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Plan for Air Pollution Research in the Texas Gulf Coast Area

Volume I. Plan for Air Quality Studies

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In response to Congressional mandates, the U. S. Environmental Protection Agency will conduct an extensive study of air pollution related problems in the Texas Gulf Coast Area. As an initial effort, EPA awarded a contract to review the existing technical information and record the local viewpoint on air pollution problems in the area, define research needs, and design experimental studies addressed to these needs. Results are presented in 5 volumes. Volume I describes and discusses a research plan for air quality studies.

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PLAN FOR AIR POLLUTION RESEARCH IN THE TEXAS GULF COAST AREA

Volume I. Plan for Air Quality Studies

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ABSTRACT

The purpose of this study was to develop a plan for air pollution research in the Texas Gulf Coast Area (TGCA). The plan will be used to support a U.S. Environmental Protection Agency study of air pollution problems in the TGCA.

Key issues associated with air pollution in the TGCA were identified. From these issues, a number of hypotheses were developed and prioritized. Six program options for air pollution research were recommended which would provide the most comprehensive and cost-effective means of data collection and analysis.

The programs recommended were:

- Support Program for Comprehensive Health Effects Studies
- Program for Ambient Air Sampling and Model Development/ Validation
- Program to Identify the Occurrence and Distribution of Hazardous Pollutants
- Program for a Detailed Study of Airborne Aerosols
- Program for a Detailed Study of Ambient Oxidants and Hydrocarbons
- Program for a Combined Aerosol-Oxidant-Hydrocarbon Study

Detailed program plans are provided for each study, as are cost and duration estimates.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

DJF	-- December-January-February
DP	-- Dew point
EC	-- Electron Capture
EPA	-- Environmental Protection Agency
FID	-- Flame Ionization Detector
FPD	-- Flame Photometric Detector
GC/MS	-- Gas Chromatograph with Mass Spectrometer
HAOS	-- Houston Area Oxidants Study
HC	-- Hydrocarbon
HOU	-- Houston Hobby Airport
IAH	-- Houston Intercontinental Airport
IR	-- Infrared
JJA	-- June-July-August
MAM	-- March-April-May
NMHC	-- Non-Methane Hydrocarbon
NOAA	-- National Oceanic and Atmospheric Administration
PA	-- Particulate
PAN	-- Peroxyacetyl Nitrate
ppb	-- Parts per billion
ppm	-- Parts per million
PSD	-- Prevention of Significant Deterioration
RH	-- Relative Humidity
RSP	-- Respirable

SMSA	-- Standard Metropolitan Statistical Area
SON	-- September-October-November
SwRI	-- Southwest Research Institute
TACB	-- Texas Air Control Board
TEM	-- Temperature
TC	-- Thermal Conductivity
TGCA	-- Texas Gulf Coast Area
TGCS	-- Texas Gulf Coast Study
THC	-- Total Hydrocarbon
TS	-- Total Sulfur
UV	-- Ultraviolet
UH	-- University of Houston
WD	-- Wind Direction
WS	-- Wind Speed
WSU	-- Washington State University

SYMBOLS

Be^7	-- beryllium-7
CH_4	-- methane
CO	-- carbon monoxide
Cr	-- chromium
H_2S	-- hydrogen sulfide
$\mu g/m^3$	-- microgram per cubic meter
Mn	-- manganese
Ni	-- nickel
NO	-- nitric oxide
NO_2	-- nitrogen dioxide
NO_x	-- oxides of nitrogen
O_3	-- ozone
O_x	-- oxidant
P^{32}	-- phosphorus- 32
Pb	-- lead
SO_2	-- sulfur dioxide
SO_4	-- sulfate
SO_x	-- oxides of sulfur

SECTION 1

INTRODUCTION

The U.S. Environmental Protection Agency is planning a three year, $3,000,000 study of air pollution problems in the Texas Gulf Coast Area (TGCA). The main purpose of this study is to investigate the nature, sources, and fate of air pollution in the TGCA, with special emphasis on the health effects of air pollution. Houston will be the focal point of the Texas Gulf Coast Study (TGCS), since considerable data are available for Houston; its environment is similar to the rest of the TGCA; and it is the most rapidly growing part of the TGCA. Figure 1-1 shows Houston and surrounding areas, including Harris County and adjacent counties. This area represents the combined Houston and Galveston Standard Metropolitan Areas with the addition of Chambers County. The immediate Houston vicinity is shown in more detail in Figure 1-2. Additional information concerning the Texas Gulf Coast Planning Study, of which this document is a part, are provided in the following:

- Volume II. Plan for Health Effects Studies
- Volume III. Summary of Previous Air Quality Studies and Data
- Volume IV. Summary of Previous Health Effects Studies and Data
- Volume V. Local Viewpoints on Research Needs

This volume (I) provides a framework for the investigation of the air pollution problem in the Houston area, in conjunction with Volume II issued by Southwest Research Institute (SwRI) concerning the health effects aspects of the problem. Section 2 describes the general nature of the air pollution problem, followed by a more specific characterization of air pollution in the TGCA in Section 3. Next, issues are defined in Section 4, and for these issues, hypotheses are also listed. Section 5 describes a number of project options which are designed to test the hypotheses and to help resolve the issues. Total costs and priorities for the overall program are discussed in Section 6, with a description of the expected agency cooperation in Section 7.

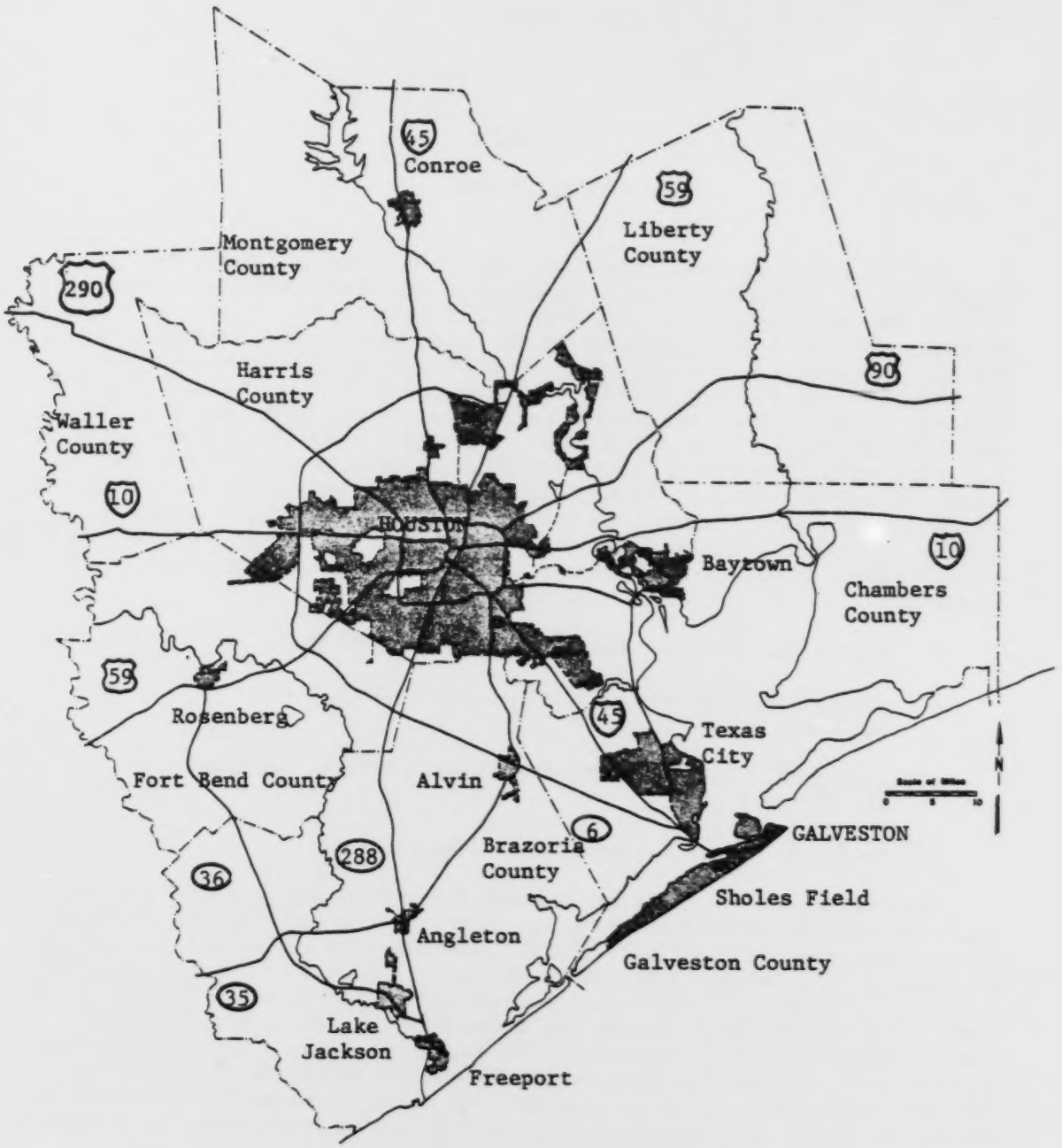

Figure 1-1. Texas Gulf Coast Study area.

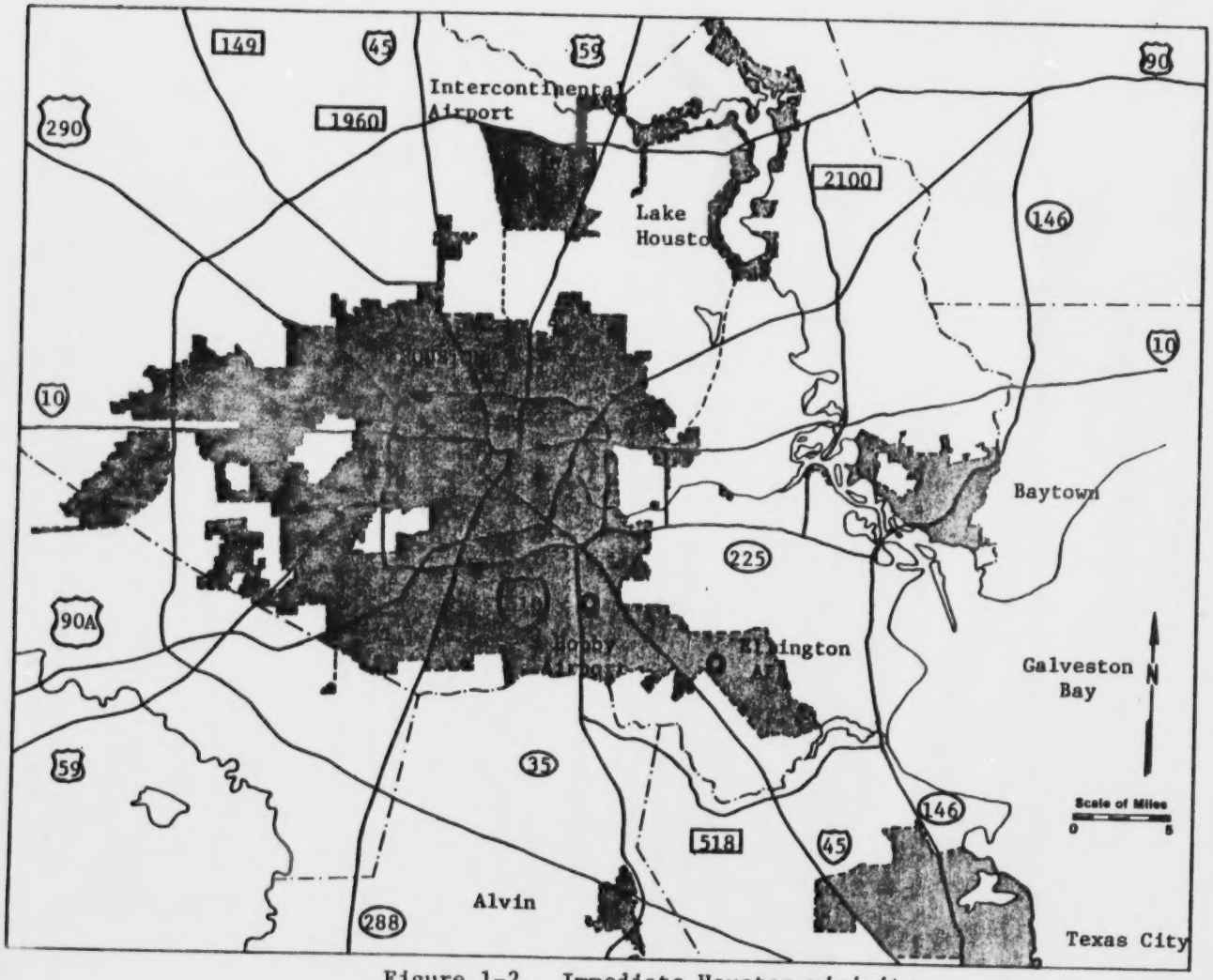

Figure 1-2. Immediate Houston vicinity.

SECTION 2

NATURE OF THE AIR POLLUTION PROBLEM

Several basic questions need to be discussed, concerning the general nature of the air pollution in the TGCA:

- What are the pollutants?
- What are the impacts of these pollutants?
- Where do the pollutants originate?
- What changes occur in the composition and distribution of pollutants in the atmosphere?
- What are the fates of the pollutants?

Significant progress has been made toward answering these questions, but many important aspects remain unanswered. Additional knowledge relevant to these questions must be gained from present and future studies to achieve an economical and effective solution to Houston's air pollution problems.

POLLUTANT DEFINITION AND DESCRIPTION

To determine what is polluting the air, it is first necessary to define air pollution. The Clean Air Act Amendments of 1977 (PL 95-95, August 7, 1977), approved by the U.S. Congress, defined the term 'air pollutant' to mean "any air pollution agent or combination of such agents, including any physical, chemical, biological, radioactive (including source material, special nuclear material, and byproduct material) substance or matter which is emitted into or otherwise enters the ambient air". However, for the purpose of defining air quality criteria and control techniques, the Clean Air Act includes only air pollutants:

- which "cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare" (in the judgement of the Administrator of the Environmental Protection Agency), and
- "the presence of which in the ambient air results from numerous or diverse mobile or stationary sources."

The Clean Air Act further defines that "all language referring to effects on welfare includes, but is not limited to, effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility,

climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well being." Consequently, air pollutants can be judged harmful because of effects caused while they are airborne, and/or after they have been removed to the earth's surface. Also, air pollutants can be natural, such as wind blown dust or volcanic emissions, but they are more frequently man-made near urban areas. Air pollutants can be broadly classified into two major categories:

- particulate matter and
- gaseous matter.

Particulate matter or aerosols include both liquid and solid particles suspended in the atmosphere, such as mists, dust, fumes, condensation nuclei, and smoke, while gaseous matter includes gases and vapors. Table 2-1 provides a classification of major types of air pollutants, their precursors, and other important components. In addition to these components, another important factor to consider for particulate matter is the particle size. The fate of particulate matter in the human respiratory system is a direct function of particle size, shape and density (or aerodynamic diameter). Inertial deposition and light scattering coefficient (atmospheric visibility) are also dependent upon particle size.

Several of the pollutants cateogrized in Table 2-1 have been identified as criteria pollutants for which state and national ambient air quality standards have been established (Table 2-2).

POLLUTANT IMPACT

The most important impact of air pollution is on public health. The health effects of air pollution will be discussed in a separate report by SwRI for the Health Study Designs. Air pollution can also reduce atmospheric visibility, produce unpleasant odors, damage property, and injure plant and animal life. Low atmospheric visibilities can be hazardous to aircraft and are generally considered aesthetically undesireable. Similarly, some pollutant odors are considered very offensive, or annoying. Significant economic impacts can occur from corrosion of materials and injury to crops. These economic effects can be caused by various forms of air pollution, including oxidants and certain aerosols, as well as by products of air pollution such as acid rainfall or soot deposits. Other detrimental effects on animals or plants may be viewed as inhumane or aesthetically disagreeable.

One final aspect of air pollution impacts that requires attention is the effect of air pollution on insolation. Particulates in the atmosphere may alter local or even global climates by absorbing and scattering sunlight that would otherwise reach the ground. Increased levels of carbon dioxide in the atmosphere would influence climate by trapping more heat in the atmosphere. Finally, certain gases, such as fluorocarbons, may reach and deplete the stratospheric ozone layer, thus causing an increase of harmful ultraviolet radiation at the ground level.

TABLE 2-1. MAJOR CLASSIFICATION OF AIR POLLUTANTS AND CONTAMINANTS

Classification	Major Components
PARTICULATE MATTER	
Inorganic	
Sulfur Compounds	Sulfate ($SO_4^{=}$), Sulfites ($SO_3^{=}$), Sulfides ($S^{=}$), Sulfuric Acid (H_2SO_4)
Nitrogen Compounds	Nitrate (NO_3^-), Ammonium (NH_4^+), Nitrite (NO_2^-)
Halogen Compounds	Chlorides (Cl^-), Fluorides (F^-), Bromides (Br^-), Iodide (I^-), Chlorates
Elemental Carbon	Elemental Carbon (C)
Other Non-Metals and their Compounds	Silicon (Si), Boron (B), Phosphorus (P), Arsenic (As)
Alkali and Alkaline-Earth Metals and their Compounds	Calcium (Ca), Sodium (Na), Potassium (K), Magnesium (Mg), Beryllium (Be), Lithium (Li)
Other Metals and their Compounds	Iron (Fe), Lead (Pb), Zinc (Zn), Manganese (Mn), Copper (Cu), Vanadium (V), Titanium (Ti), Nickel (Ni), Tin (Sn), Chromium (Cr), Cadmium (Cd), Antimony (Sb), Cobalt (Co), Asbestos
Radioactive Isotopes	Beryllium-7 (Be^7), Uranium-238 (U^{238}), Radium-226 (Ra^{226}), Polonium-210 (Po^{40}), Phosphorus-32 (P^{32})
Organic	
Biological	Pollen, Molds, Spores, Fungi, Bacteria, Virus
Non-Biological	Hydrocarbons (HC), Organic Acids, Epoxides, Polymers, Polynuclear Aromatics, Halogenated Organics, Heterocyclic Organics, Oxygenated Organics
GASEOUS MATTER	
Oxidants	Ozone (O_3), Peroxyacetyl Nitrate (PAN), Chlorine (Cl_2)
Oxides of Nitrogen	Nitrogen Dioxide (NO_2), Nitric Oxide (NO)
Other Nitrogen Compounds	Ammonia (NH_3), Hydrogen Cyanide (HCN), Amines, Nitric Acid (HNO_3)
Oxides of Carbon	Carbon Monoxide (CO), Carbon Dioxide (CO_2)
Other Carbon Compounds	Methane (CH_4), Hydrocarbons (HC), Aromatics, Paraffins, Olefins, Alkanes, Alkynes, Alcohols, Aldehydes, Ketones, Carboxylic Acids, Heterocyclic Organics, Polycyclic Organics, Esters, Ethers
Sulfur Compounds	Sulfur Dioxide (SO_2), Hydrogen Sulfide (H_2S), Mercaptans, Sulfides, Disulfides
Halogen Compounds	Chlorine Compounds, Bromine Compounds, Iodine Compounds, Fluorocarbons
Radioactive Gases	Radon-222 (RN^{222})

TABLE 2-2. CRITERIA POLLUTANTS

Pollutant	Averaging Interval	Maximum Concentrations: National Primary Standard ($\mu g/m^3$)	Maximum Concentrations: National Primary Standard (ppm)	Maximum Concentrations: National Secondary Standard ($\mu g/m^3$)	Maximum Concentrations: National Secondary Standard (ppm)
Sulfur Dioxide (SO_2)	Annual	80	0.03	---	---
	24-Hour*	365	0.14	---	---
	3-Hour*	---	---	1,300	0.50
Total Suspended Particulate (TSP)	Annual***	75	---	60	---
	24-Hour*	260	---	150	---
Lead (Pb)	3-Month	1.5	---	---	---
Carbon Monoxide (CO)	8-Hour*	10,000	9.00	10,000	9.00
	1-Hour*	40,000	35.00	40,000	35.00
Photochemical Oxidant-Ozone (O_3)	1-Hour*	160	0.08	160	0.08
Non-Methane Hydrocarbons (6-9 am) (NMHC)**	3-Hour*	160	0.24	160	0.24
Nitrogen Dioxide (NO_2)	Annual	100	0.05	100	0.04

*Not to be exceeded more than once per year.
**Guideline.
***Geometric Mean.

All of these impacts - on health, visiblity, materials, animals, plants, and climate - need to be considered in the design of useful air pollution control strategies. However, the effects of air pollution on public health are of initial and primary concern.

POLLUTANT SOURCES

Pollutants in the atmosphere are commonly referred to as primary and secondary in origin. Primary pollutants are those which are emitted directly into the air, while secondary pollutants are those which are formed by chemical reactions or physical interactions in the atmosphere. In addition, several important classifications are used to distinguish pollutant sources:

- point and area,
- stationary and mobile,
- anthropogenic and natural, and
- local and distant.

For modeling purposes, sources are usually divided into point and area categories. Point sources are large emission sources concentrated from a small area, such as a stack, vent, or building, while area sources consist of numerous small sources covering a larger area, commonly greater than one square mile. Thus, area sources include mobile sources such as combustion-driven vehicle emissions and widespread sources such as vehicle entrained dust and emissions from home heating, gasoline transfer, painting, and dry cleaning. Stationary sources are generally large industrial sources, but include both point and area source that are stationary in location. For control purposes, it is helpful to distinguish between anthropogenic (man-made) and natural sources as well as local and distant sources. Local sources are generally considered sources within a city or metropolitan area, while distant sources are sources from well beyond the metropolitan area, sometimes as far as 1,000 miles beyond or more.

POLLUTANT TRANSPORT AND TRANSFORMATION

The distribution, concentration, and composition of pollutants in the atmosphere are affected by:

- meteorological conditions,
- chemical reactions, and
- other particle and gaseous interactions.

Meteorological conditions of wind, sunshine, and cloud cover strongly affect pollutant dispersion and transport, which in turn affect pollutant distribution and concentration. Also, temperature, humidity, sunshine, cloud cover, and precipitation influence chemical reaction rates and particle and gaseous interactions. Chemical reactions, which form secondary pollutants, occur between atmospheric gases, within liquid particles, and on the

surface of liquid and solid particles. Gases and particles interact by means of absorption and adsorption, and vapors can condense to form particles.

POLLUTANT FATE

All of the previously described factors, which cause changes in pollutant composition and concentration, ultimately affect pollutant fate. Chemical reactions may change some pollutants into relatively harmless products or even remove them from the atmosphere at the earth's surface. Particles and gases are trapped in the respiratory systems of animals and man by interception, impaction, diffusion, absorption, and adsorption. Precipitation scavenges particulate matter as well as water soluble gases, delivering them to the soil and surface waters. Finally, mixing of the atmosphere sooner or later disperses pollutants to less harmful concentrations, and the large scale movements of the atmosphere transport pollutants over long distances. However, increasing emissions on a regional and global scale may cause significant increases in regional and worldwide air pollution levels.

SECTION 3

CHARACTERIZATION OF AIR POLLUTION AND METEOROLOGY IN THE TEXAS GULF COAST AREA

Considerable air pollution and meteorological data have been collected for the Houston area by public and private organizations. A summary of this information has been provided in the Gulf Coast Planning Study Resource Document (Volume III) (1) previously prepared as part of the TGCS planning project. The existing data provide a useful characterization of the air pollution problem in the Houston area. These data consist of three major categories:

- emissions,
- ambient pollutant, and
- meteorological data.

A review of the data is helpful for making comparisons between air pollution problems that exist in the Houston area and air pollution problems in other regions of the nation, and for determining which pollutants should be emphasized for study.

EMISSIONS DATA

Emissions data compiled by the TACB for the Houston area during 1973 are summarized in Table 3-1. The 1975 TACB emissions data have not been completely compiled by county, so that only partial totals are available for 1975 (Table 3-2). More detailed breakdowns of some of these pollutant emissions are available for specific point sources, but such detailed emissions are not widely available for all point and area sources. However, plans are currently being made to provide greater detail, especially for hydrocarbons, for the 1975 and 1978 TACB Emissions Inventories. Also, the EPA is planning to compile area source data for the Houston area for 1978. Seasonal variations are indicated on some individual TACB inventory questionnaires, but otherwise, emissions data for time periods less than a year are not available. Spacial distributions of 1975 point source emissions for HC, NO_x, SO_x, and PA are presented in Volume III (1).

The most significant aspect of the 1973 emissions totals is the predominance of point sources as the major source of emissions in the Houston area. Point sources accounted for 80 percent of the 1973 hydrocarbon emis-

TABLE 3-1. HOUSTON AREA 1973 EMISSIONS TOTALS

		Pollutant - tons/year				
		NO_x	SO_2	THC	CO	PA
Houston Study Area	Total Emissions	498,836	206,269	687,505	1,445,331	91,293
	Point Source	378,679	191,637	553,022	858,449	60,227
	Area Source	120,157	14,632	134,483	586,882	31,066
Harris County	Total Emissions	236,839	157,076	369,293	888,902	58,605
	Point Source	155,059	147,734	272,162	445,682	40,701
	Area Source	81,780	9,342	97,131	443,220	17,904
Galveston County	Total Emissions	79,088	36,357	111,346	257,498	10,378
	Point Source	69,725	33,718	101,704	216,869	8,367
	Area Source	9,363	2,639	9,642	40,629	2,011
Brazoria County	Total Emissions	108,525	10,573	173,042	151,680	9,267
	Point Source	100,735	9,708	165,479	122,506	6,771
	Area Source	7,790	865	7,563	29,174	2,496
Fort Bend County	Total Emissions	19,158	601	6,150	19,896	4,878
	Point Source	13,964	251	962	178	1,542
	Area Source	5,194	350	5,188	19,718	3,336
Waller County	Total Emissions	6,551	170	7,303	6,296	1,158
	Point Source	4,455	8	5,578	128	133
	Area Source	2,096	162	1,725	6,168	1,025
Montgomery County	Total Emissions	18,350	574	11,463	90,344	2,037
	Point Source	11,958	173	5,125	68,002	663
	Area Source	6,392	401	6,338	22,342	1,374
Liberty County	Total Emissions	4,425	254	3,636	14,064	2,309
	Point Source	981	6	250	1,018	595
	Area Source	3,444	248	3,386	13,046	1,714
Chambers County	Total Emissions	25,900	664	5,272	16,651	2,661
	Point Source	21,802	39	1,762	4,066	1,455
	Area Source	4,098	625	3,510	12,585	1,206

Source: Texas Air Control Board (2).

TABLE 3-2. 1975 EMISSIONS TABLE FOR THE COMBINED HOUSTON AND GALVESTON SMSA'S*

Pollutant	Tons	% of Total
Total Hydrocarbon Compounds (Non-Methane)	343,078	100
Point	209,103	61
Area	133,975	39
Total NO_x	327,094	100
Point (for HC sources only)	200,209	61
Area	126,885	39
Total SO_x	NA	--
Point	NA	--
Area	15,547**	--
Total CO	NA	--
Point	NA	--
Area	562,964**	--
Total Particulate	NA	--
Point	NA	--
Area	32,144**	--

* Chambers County not included.

** Includes 1976 emissions data for Harris County.

NA: Not available.

Sources: Texas Air Control Board (3)(4).

sions, 76 percent of the NO_x emissions, 93 percent of the SO_x emissions, 59 percent of the CO emissions, and 66 percent of the particulate emissions totals for the 8-county Houston area. Most of these point source contributions come from industrial fuel combustion and process losses. Exhaust emissions from gasoline-fueled land transportation, according to the 1973 data, accounted for only 16 percent of the hydrocarbon emissions, 16 percent of the NO_x emissions, 1 percent of the SO_x emissions, 38 percent of the CO emissions, and 9 percent of the particulate emissions from the Houston area. Similar breakdowns for contributions to total emissions have not been compiled for the 1975 TACB Emissions Inventory. The relative contributions of point sources may have decreased significantly since 1973 because of increased control efforts. The new 1978 inventory should indicate whether any such changes have occurred.

AMBIENT POLLUTANT DATA

Ambient pollutant data from Texas Air Control Board (5) (TACB) and City of Houston (6) monitors in the Houston area are summarized in Table 3-3. The locations of these monitors are shown in Figure 3-1. Ambient pollutant data are available for only the major pollutants (O_3, NO_x, NO_2, NO, total HC, NMHC, CH_4, SO_2, H_2S, total sulfur, and CO) on a long-term continuous hourly basis (although frequent short gaps appear throughout the data). Intermittent (non-continuous) data for total oxidants, total sulfur, total aldehydes, ammonia, and total suspended particulate cover a longer time span, but observations are generally for one 24-hour average every six days. The total sulfur and total oxidant measurements (by bubbler) have been abandoned because of serious problems with the measurement techniques. Detailed chemical analyses have been performed for most particulate samples (Table 3-4). A few air pollution studies have undertaken more extensive and detailed monitoring for up to about five months. Pollutants such as PAN, halocarbons, individual hydrocarbons, respirable aerosols, aldehydes, freon, beryllium-7 and pollen, as well as particle size distribution, have been measured during these short-term intensive studies.

The most significant aspects of the pollutant data are the relatively high ozone, hydrocarbon and particulate levels which have exceeded their respective standards. Hourly average ozone levels of up to 0.321 parts per million (ppm) have been measured, and nine out of ten long-term monitoring sites have measured ozone levels exceeding 0.230 ppm. Only the Clute monitor near the coast has not reported such high ozone levels; a maximum of 0.186 ppm has been reported.

All seven of the locations which regularly measure non-methane hydrocarbons (NMHC) in the Houston area have greatly exceeded the three-hour 6-9 AM guideline for this pollutant. One City of Houston site has reported a 6-9 AM average as high as 18.6 ppm, and the highest 6-9 AM average at a TACB site has been 6.4 ppm. All of these long-term sites have measured NMHC well over the 0.24 ppm 6-9 AM standard during each of the last three years.

TABLE 3-3. SUMMARY OF IMPORTANT AMBIENT AIR MEASUREMENTS FOR THE HOUSTON AREA 1975-1977.
(All measurements in parts per million, except TSP in micrograms per cubic meter.)

		Lang (NW)	Aldine (NE)	Parkhurst (NE)	Mae Drive (E)	Clinton (E)	Crawford (CENT)	MacGregor (CENT)	Fuqua (SE)	Texas City	Clute
OZONE											
Maximum	1975	--	0.321	0.267	0.288	0.307	0.254	0.198	0.285	0.222	0.160
Hourly	1976	--	0.272	0.286	0.297	0.278	0.223	0.270	0.289	0.225	0.186
Average	1977	0.256	0.270	0.302	0.222	0.205	0.309	0.254	0.281	0.236	0.185
Number of	1975	--	251	242	202	214	186	116	255	288	187
Hours over	1976	--	397	534	279	518	188	243	289	311	205
.08 ppm	1977	103	322	481	255	224	119	170	281	188	133
Number of	1975	--	218	221	180	188	171	96	255	233	145
Hours over	1976	--	307	447	232	446	167	219	434	257	152
.08 ppm	1977	88	269	404	224	213	105	129	129	179	84
May-Oct Only											
NITROGEN DIOXIDE											
Maximum	1975	--	0.13	0.13	0.21	0.35	0.41	--	--	0.10	0.09
Hourly	1976	--	0.14	--	0.32	0.24	0.29	0.12	--	0.29	0.11
Average	1977	--	0.11	0.14	0.18	--	0.13	--	--	0.12	0.09
Annual	1975	--	0.02	*	0.03	*	*	--	--	0.01	0.01
Average	1976	--	0.02	--	0.02	*	*	*	--	0.01	0.01
	1977	--	0.02	*	0.03	--	*	--	--	0.02	0.01
NON-METHANE HYDROCARBON											
Highest	1975	--	2.1	18.6	3.9	6.3	12.4	--	--	5.4	3.1
6-9 am	1976	--	3.9	7.0	3.4	10.1	7.6	--	--	3.8	4.5
Average	1977	--	6.2	15.5	6.1	4.2	10.3	--	--	2.9	6.4
SULFUR DIOXIDE											
Maximum	1975	--	0.11	--	0.20	0.56	0.17	--	--	0.21	0.02
Hourly	1976	--	0.01	--	0.12	0.63	0.26	--	--	0.31	0.09
Average	1977	--	0.01	--	0.11	0.44	--	--	--	0.03	0.02
Maximum	1975	--	0.10	--	0.13	0.53	0.14	--	--	0.12	0.01
3 hour	1976	--	0.01	--	0.07	0.43	0.19	--	--	0.21	0.03
Average	1977	--	0.01	--	0.06	0.34	--	--	--	0.02	0.01
Annual	1975	--	0.00	--	0.00	*	*	--	--	0.00	0.00
Average	1976	--	0.00	--	0.00	*	*	--	--	0.00	0.00
	1977	--	0.00	--	0.00	*	--	--	--	0.00	0.00
TOTAL SUSPENDED PARTICULATE											
Maximum	1975	149	153	150	204	--	163	149	205	126	180
24 Hour	1976	227	134	220	198	--	119	175	228	207	185
Average	1977	273	1041	200	841	334	629	252	240	1203	781
Annual	1975	57	64	63	82	--	71	62	65	59	74
Geometric	1976	60	65	64	90	--	69	53	60	57	71
Mean	1977	62	74	67	91	142	76	53	63	64	89

*Not available at present

Sources: Texas Air Control Board (5)
City of Houston (6)

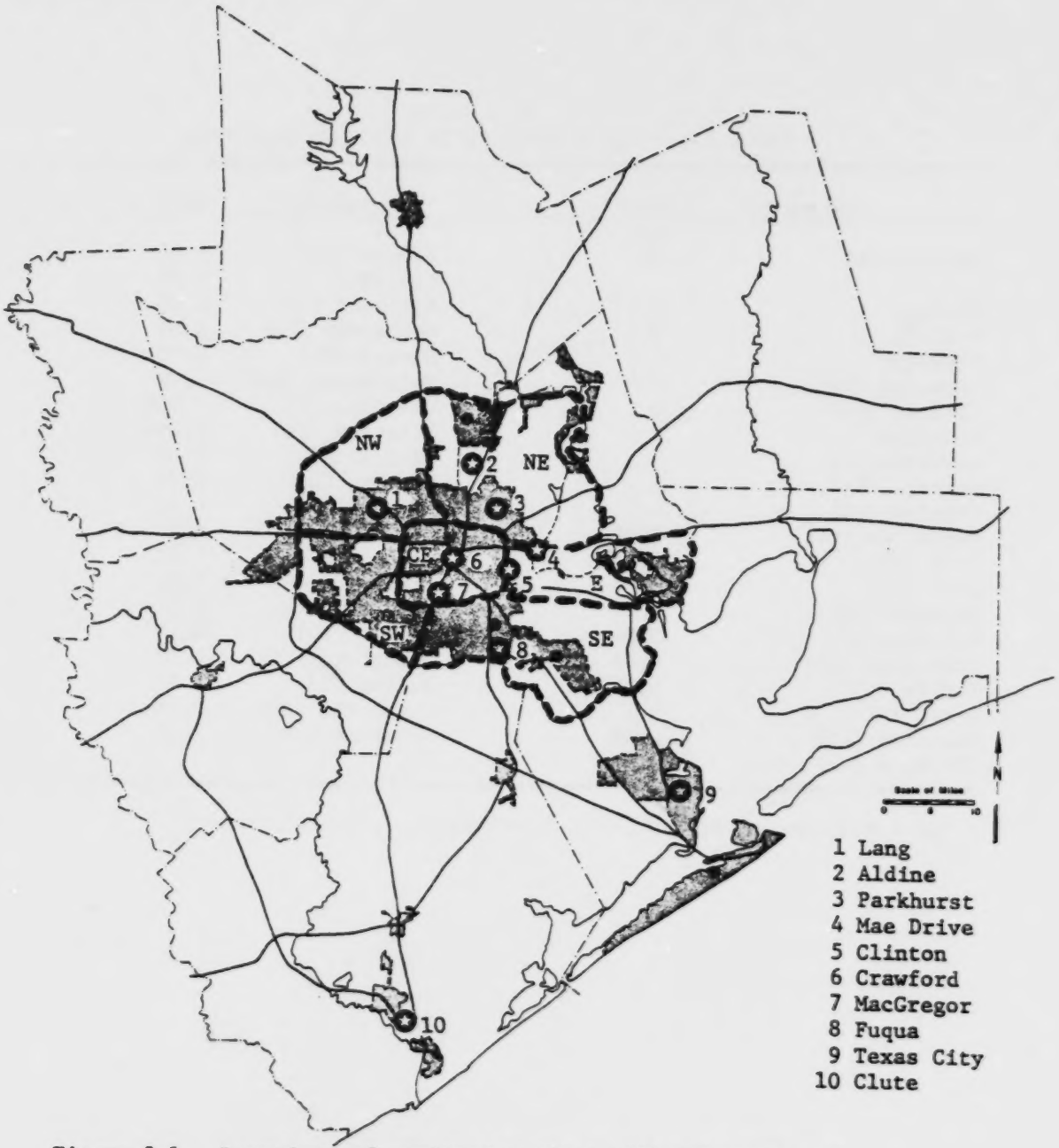

Figure 3-1. Locations of monitoring sites with data reported in Table 3-3.

TABLE 3-4. TSP PARAMETERS IN THE TACB DATA FILE

Parameter	MDL*	Parameter	MDL*
Particulate	1.0	Copper (Cu)	0.02
Nitrate	0.1	Tin (Sn)	0.08
Sulfate	0.1	Antimony (sb)	0.04
Organics	0.1	Manganese (Mn)	0.06
Aluminum (Al)	0.6	Nickel (Ni)	0.02
Silicon (Si)	0.2	Molybdenum (Mo)	0.02
Fluoride	0.1	Vanadium (V)	0.004
Chloride (Cl)	0.1	Titanium (Ti)	0.006
Arsenic (As)	0.8	Zinc (Zn)	0.02
Cadmium (Cd)	0.8	Cobalt (Co)	0.04
Beryllium (Be)	0.006	Calcium (Ca)	0.01
Iron (Fe)	0.04	Sodium (Na)	0.1
Lead (Pb)	0.04	Strontium (Sr)	0.02
Bromide (Br)	0.04	Potassium (K)	0.01
Rubidium (Rb)	0.04	Magnesium (Mg)	0.1
Zirconium (Zr)	0.02	Barium (Ba)	0.1
Iodide (I)	0.08	Phosphorus (P)	0.06
Boron (B)	0.1	Sulfur (S)	0.04
Thallium (Tl)	0.08	Germanium (Ge)	0.06
Chromium (Cr)	0.06	Selenium (Se)	0.04

* MDL - Minimum detectable limit in micrograms per cubic meter

Total suspended particulate (TSP) levels have been measured in excess of the 75 microgram per cubic meter ($\mu g/m^3$) geometric mean annual standard, as well as the 260 $\mu g/m^3$ 24-hour standard, at several sites in the Houston area. Of the ten sites shown in Table 3-3, four have exceeded the annual standard during the last three years. In addition to these sites, TSP is monitored at many other locations in the Houston area. Several of these sites have recorded levels that violated the national ambient air quality standards.

The annual standard for nitrogen dioxide (NO_2) has not been exceeded at any of the eight city and state continuous monitors, and only the 24-hour standard for sulfur dioxide (SO_2) has been exceeded at one of six city and state continuous monitors. The City of Houston Clinton site recorded a 24-hour average of 0.161 ppm on December 11, 1975, which exceeds the standard of 0.140 ppm. However, SO_2 levels have not been observed over the standards at any of these sites since that time. Consequently, no violations of the national SO_2 standard have been reported.

Peroxyacetyl nitrate (PAN) levels have been monitored on a short-term basis during two air pollution studies in the Houston area. Scientists from Washington State University (7) measured PAN levels from July 2 to 23, 1976 at one location in northwest Houston (Lang). They found only two occasions on which PAN persisted into the night (at concentrations less than 1 ppb) with a daily 10 AM to 4 PM average of only 1.0 ppb. The highest hourly average measurement was 11.5 ppb. PAN levels were also measured from June through October, 1977 at three locations (Aldine, Crawford, and Fuqua) in the Houston area as a part of the Houston Area Oxidants Study (HAOS). The HAOS measurements (8) showed a maximum monthly average of 1.2 ppb which occurred during July, 1977 at the Aldine site, with a peak instantaneous reading of 15.6 ppb during October, 1977 also at the Aldine site. The average levels over the 5-month study period ranged from 0.58 ppb at the Crawford site (downtown) to 0.90 ppb at the Aldine site (north of Houston). Both the WSU and HAOS measurements showed relatively high PAN levels concurrent with relatively high oxidant levels, although the reverse was not always true. During the HAOS monitoring period, there were times when the oxidant levels were high, while PAN levels were low.

The WSU study identified about 75 hydrocarbon species which accounted for about 90 percent of the total non-methane hydrocarbons present, during July, 1976. Integrated samples were gathered at three sites (Lang, Aldine, and Fuqua) with grab samples from other locations. These measurements showed large variations in composition and total NMHC with distance and time. Table 3-5 provides a summary of the 6-9 AM detailed hydrocarbon measurements from July, 1976. Afternoon hydrocarbon levels were generally lower by about a factor of three, compared to the 6-9 AM measurements.

Other detailed hydrocarbon measurements have been obtained during studies in July 1973 and July - August 1974 by the University of Houston (9), in 1975 by the Texas Air Control Board (10), from June-October 1977 for HAOS, and from September 15 to October 15, 1978 for the Houston Air Pollution

TABLE 3-5. INDIVIDUAL HYDROCARBON MEASUREMENTS FROM SAMPLES COLLECTED BETWEEN 6 AM AND 9 AM DURING JULY 1976 BY WSU ($\mu g/m^3$)

	LANG SITE (17 Days)		ALDINE SITE (10 Days)		FUQUA SITE (12 Days)	
	Monthly Average	Maximum	Monthly Average	Maximum	Monthly Average	Maximum
Ethane	27.0	118	18.0	33.0	18.0	73.0
Ethylene	13.0	20.0	13.5	23.0	34.0	126
Acetylene	18.0	31.5	6.0	10.0	10.0	32.0
Propane	70.5	621	34.5	58.0	40.5	110
Propene	21.0	82.5	7.5	13.0	19.0	145
i-Butane	39.0	205	20.5	33.0	32.0	148
n-Butane	116	846	37.0	64.0	34.5	79.0
1-Butene	4.0	10.0	2.0	3.0	2.5	6.0
i-Butene	5.5	8.5	3.0	4.0	2.5	8.5
t-2-Butene	8.0	24.0	3.0	5.5	3.5	12.0
c-2-Butene	*	*	*	*	*	*
i-Pentane	109	599	34.5	65.0	37.0	77.0
n-Pentane	93.5	296	19.0	32.0	26.0	85.5
1-Pentene	4.0	19.0	1.5	2.5	1.5	4.0
2-Methylpentane	28.0	125	12.5	23.0	10.0	23.0
3-Methylpentane	19.5	73.5	8.0	13.5	7.5	16.0
n-Hexane	18.0	48.0	12.5	28.0	13.0	23.5
2,4-Dimethylpentane	5.5	14.5	2.5	4.0	2.5	7.0
Benzene	18.0	42.5	10.0	14.0	10.5	23.5
Toluene	37.5	61.0	70.5	173	22.0	39.0
Ethylbenzene	10.0	17.0	68.5	224	10.0	36.0
p&m-Xylene	25.5	40.5	225	778	26.5	137
o-Xylene	11.5	19.5	119	385	14.0	80.0
1,3,5-Trimethylbenzene	5.0	11.5	163	975	5.0	19.0
1,2,4-Trimethylbenzene	12.0	30.0	180	522	32.5	258
1,2,3-Trimethylbenzene	3.5	7.0	41.5	125	5.5	37.0
All of the above HC	723	2527	1110	2893	421	889
All other NMHC	380	1662	2239	8005	387	2051
Total NMHC	1103	4189	3349	10898	808	2728

* less than 0.5 $\mu g/m^3$

Source: Westberg (7)

study (HAPS). The HAOS and HAPS data are not available at this writing, but the other studies have reported hydrocarbon levels and variations similar to the WSU data. The UH study showed a much higher percentage of samples containing olefins in the downtown Houston area (65% of 377 samples) compared to Pasadena (13% of 379 samples) and La Porte (4% of 108 samples).

Total aldehydes and formaldehyde have been measured on a non-continuous basis (one 24-hour average about every six days) by bubblers at numerous locations in the Houston area since 1973 (11). More sparse data are available from earlier years. During the period from 1973 through 1977, sites reporting at least 30 samples per year showed annual geometric means that ranged from 3 to 10 $\mu g/m^3$ in Harris County and from 2 to 19 $\mu g/m^3$ in Galveston County (see Table 3-6). Maximum 24-hour averages for each of these years ranged from 7 to 111 $\mu g/m^3$ in Harris County and from 5 to 270 $\mu g/m^3$ in Galveston County. Attempts were made during the HAOS (12) program to identify individual constituents of aldehydes. However, the only component that was found in measurable quantities (over 10 ppb) was formaldehyde. Comparisons of simulataneous measurements of total aldehydes and formaldehyde have indicated that formaldehyde is frequently a major constituent of the total aldehydes.

Ammonia has also been measured by bubblers on an intermittent basis (one 24-hour average about every six days) at most of the same sites that measure total aldehydes(11). Large variations appear in the data, with annual geometric means ranging from 3 to 97 $\mu g/m^3$ for sites in Harris County and 3 to 14 $\mu g/m^3$ for sites in Galveston County. The highest annual 24-hour averages have ranged from 7 to 977 $\mu g/m^3$ for sites in Harris County and from 8 to 1400 $\mu g/m^3$ for sites in Galveston County (only data from sites with at least 30 samples for a given year have been included in this summary).

Diurnal and/or seasonal trends are apparent for most of the pollutants that have been measured in the Houston area. Diurnal trends can only be established for pollutants monitored continuously with sampling averages covering a period no longer than about three hours. Diurnal trends for ozone, oxides of nitrogen, non-methane hydrocarbons, sulfur dioxide, and carbon monoxide have been presented in the Resource Document (1). Two types of diurnal patterns are evident for these five pollutants. One type, for ozone, shows a maximum in the early afternoon with low levels at night. The other four pollutants generally reach a maximum at night, usually in the early morning (between 3 am and 7 am CST) with a minimum during the early afternoon. A diurnal pattern for total aldehydes was reported by the UH 1973-74 study (9), using 3-hour averages, which suggested a maximum during the afternoon.

Seasonal trends are most evident for ozone and oxides of nitrogen. Hourly ozone averages show a pronounced summer maximum from May through October. Of the ten city and state sites which recorded continuous data for at least one year since 1973, five have had their highest hourly average in June, two in July, two in August, and one in May. The lowest monthly ozone maximums generally occur during January or February. Monthly averages

TABLE 3-6. TOTAL ALDEHYDE AND AMMONIA DATA SUMMARY FOR 1973-1977 FOR SITES WITH AT LEAST 30 SAMPLES PER YEAR ($\mu g/m^3$)

		HARRIS COUNTY SITES				GALVESTON COUNTY SITES			
		ANNUAL Geometric Mean		MAXIMUM 24-Hour Average		ANNUAL Geometric Mean		MAXIMUM 24-Hour Average	
		Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest
Total Aldehydes	1973	3	9	14	71	9	19	32	157
	1974	4	10	14	100	9	17	106	270
	1975	4	8	17	111	7	14	52	104
	1976	2	6	7	79	4	5	19	36
	1977	3	7	9	33	2	4	5	25
Ammonia	1973	20	97	280	992	3	14	49	1400
	1974	3	44	18	887	3	8	80	208
	1975	3	38	12	785	2	7	25	197
	1976	3	40	7	750	3	10	8	133
	1977	3	17	12	977	4	5	21	52

Source: Texas Air Control Board (11)

of all the NO_x data at the four TACB sites in the Houston area show a maximum in November or December. The lowest monthly maximums as well as the lowest monthly averages for NO_x have occurred from May through September at the four TACB sites. Sulfur dioxide levels at the few continuous-criteria sites with significant measurements have shown a winter maximum, summer minimum trend. Consistent seasonal trends are not readily apparent for NMHC and CO, although the highest monthly averages of CO have occurred in January and December.

METEOROLOGICAL DATA

Meteorological data have been recorded by the National Weather Service since 1881 at several locations in the Houston area. More recently, meteorological data have been reported from other sources in the Houston area, including ambient air monitoring programs. More detailed information about these various sources is contained in the Resource Document (1). A general view of the Houston climate can be described from this wealth of data.

The Houston sub-tropical climate is strongly influenced by warm moist tropical air originating from the Gulf of Mexico during the late spring, summer, and fall. Cool dry continental air reaches a peak of influence during the winter, with occasional outbreaks of arctic air bringing very cold and dry air to the area. Coastal effects are noticeable year-round. Temperatures show less diurnal variation near the coast, with cooler maximum temperatures and warmer minimum temperatures on the average, compared to locations farther inland. Wind speeds and humidity are slightly higher, on the average, near the coast. The normal temperature gradients along the coast cause sea breeze and land breeze effects, which are most noticeable within about 50 miles of the coast during periods of light winds and abundant sunshine. With light winds and clear skies, a land breeze normally appears within several hours after sunset, blowing from the north or northeast. Shortly after sunrise, the wind veers (turns clockwise) to the southeast, south, or southwest along the coast. This turning of the wind spreads inland during the day, causing a sea breeze to appear at later times during the day farther inland. Occasionally, with ideal conditions, the sea breeze will penetrate as far as 80 to 100 miles inland by the late afternoon, before it begins to dissipate around sunset.

National Weather Service (13) temperature, precipitation, relative humidity, and wind normals for Houston and Galveston have been presented in the Resource Document (1). In summary, monthly average daily maximum temperatures range from 62.6°F in January up to 94.3°F in August, while monthly average daily minimum temperatures range from 41.5°F in January up to 72.8°F in July at Houston (based on data from 1941-1970 that is mainly from Hobby Airport). Normal monthly precipitation totals range from 1.68 inches in March up to 5.10 inches in May at Houston (1941-1970). The long-term average relative humidity is 75 percent (1914-1959) (14), with monthly averages ranging from near 70 percent in November to near 80 percent in January. The normal annual daily range in relative humidity is from about 60 percent at noon to about 90 percent at 6 AM (CST). Montly average dew points range

from 45°F in January to 73°F in July and August, with an annual average of 60°F for Houston (1946-1965) (14).

The prevailing wind direction is from the south-southeast, but significant variations in wind direction frequency occur on a seasonal basis. Figures 3-2 and 3-3 show the seasonal variations of wind direction and speed frequencies for the Intercontinental Airport (IAH) (15) and Hobby Airport (HOU) (16). In addition, the 6 am CST wind rose for HOU is included for each season to show that significant diurnal variations of wind direction and wind speed exist. Each wind rose displays the frequency of occurrence of wind direction and wind speed. The wind direction points toward the center of the wind rose diagram, with the total frequency by direction given to the outside (thus in Figure 3-2 at IAH during March-April-May, the wind blows from the north 8.07% of the time, from the north-northeast 5.35% of the time, etc.) A scale for wind speed frequencies is shown. The summer and fall wind roses show the greatest influence of the land breeze - sea breeze regime, with much higher frequencies of wind direction from north through east at 6 am than for the entire day. Likewise, the full-day wind roses for summer and fall show much higher frequencies of wind direction from the southeast through south compared to the corresponding 6 am wind roses.

The percentage of possible sunshine ranges from 45% in January and March to 67% in June, with an annual average of 57% for Houston (IAH 1970-1977) (13). The cloudiest month is January, with an average sunrise to sunset sky cover of 6.8 tenths and 17 cloudy days, while October is the clearest month, with an average sunrise to sunset sky cover of 5.2 tenths and 11 clear days (IAH 1970-1977) (13).

The number of days per month with measureable precipitation (0.01 inch or more) ranges from seven days in September to 11 days in January, with an annual total of 103 days for Houston (1935-1970) (13). However, the number of days on which thunder is heard ranges from two days in November, December, January, and March, to 10 days in July, with an annual average of 42 days per year (1941-1970) (13). Heavy fog (visiblities of 1/4 mile or less) is most frequent during the winter with up to seven days with heavy fog during January, while June and July normally have no heavy fog occurrences. An average of 42 days with heavy fog occur each year (1948-1970) (13).

Visibilities less than seven miles occurred about 25 percent of the time at IAH (1970-1976) (12), with visibilities less than three miles occurring about 10 percent of the time on an annual basis. On a seasonal basis, visibilities less than seven miles vary from about 19 percent of the time in the summer to about 30 percent of the time during the spring (see Table 3-7). Visibilities less than three miles range from about 5 percent of the time during the summer to about 14 percent of the time during the winter. Smoke and haze with visibilities less than seven miles are reported for about 17 percent of the time on an annual basis, ranging from about 14 percent of the time in the summer to about 22 percent of the time in the spring. Dust with visibilities less than seven miles was reported for less than 1 percent

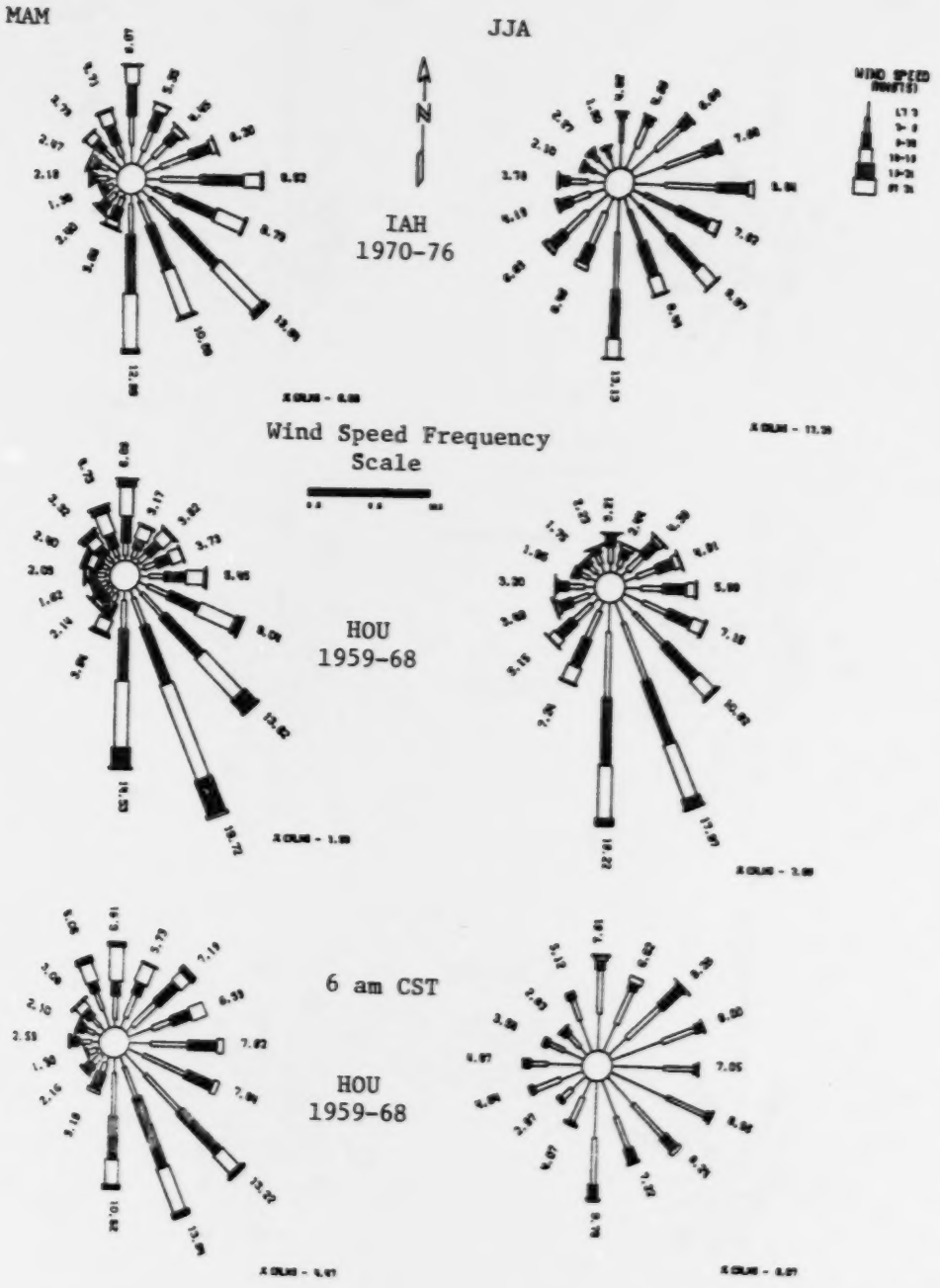

Figure 3-2. Wind rose diagrams for March-April-May (left) and June-July-August (right) for Intercontinental Airport - IAH (top), Houston Hobby Airport - HOU (middle), and Houston Hobby Airport - HOU - 6 am CST (bottom).

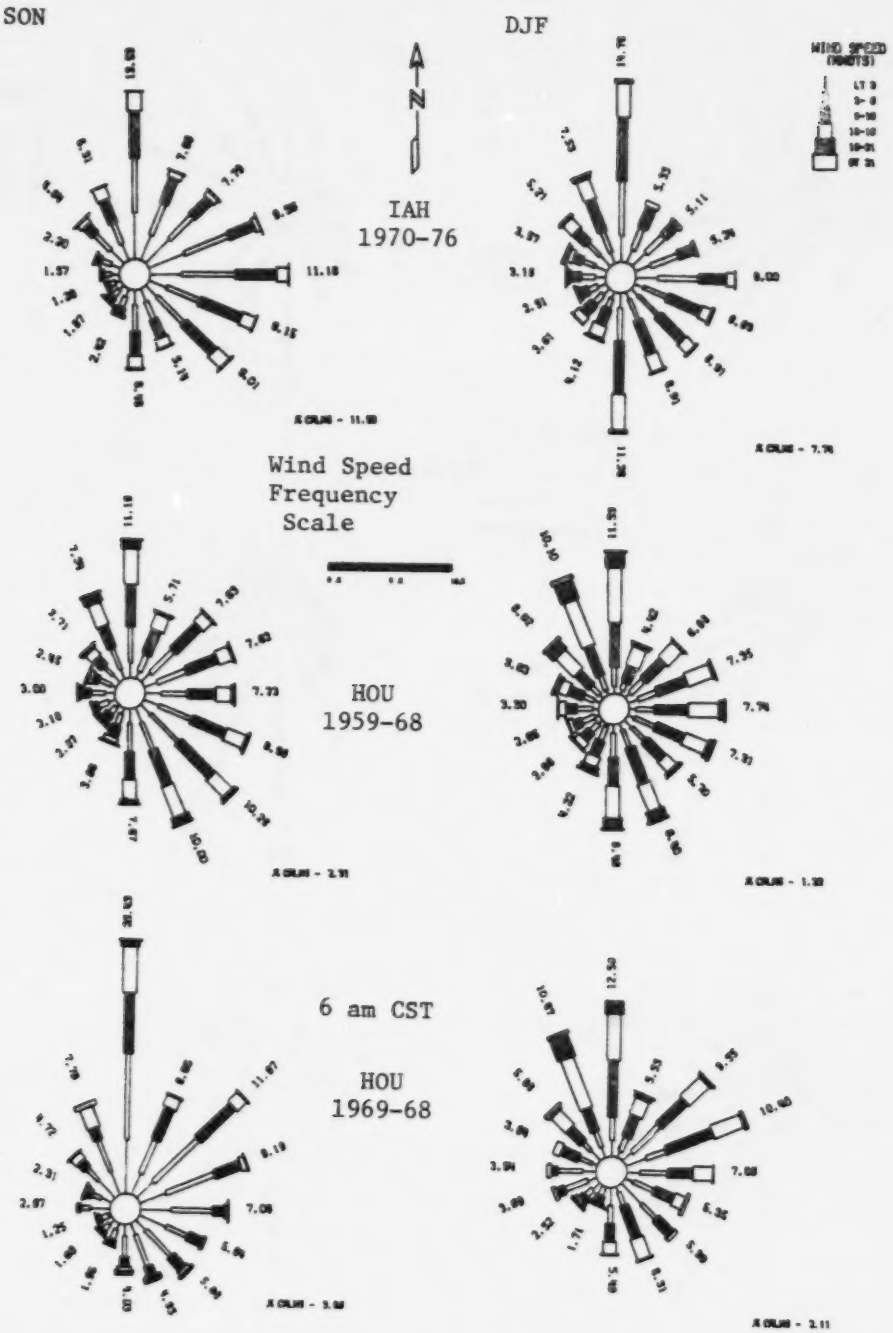

Figure 3-3. Wind rose diagrams for September-October-November (left) and December-January-February (right) for Intercontinental Airport - IAH (top), Houston Hobby Airport - HOU (middle), and Houston Hobby Airport - HOU - 6 am CST (bottom).

TABLE 3-7. RESTRICTED VISIBILITY OCCURRENCES AT THE HOUSTON INTERCONTINENTAL AIRPORT 1970-1976 (BASED ON 8 OBSERVATIONS PER DAY AT 3 HOUR INTERVALS BEGINNING AT MIDNIGHT CST EACH DAY).

	DEC-JAN-FEB		MAR-APR-MAY		JUN-JUL-AUG		SEP-OCT-NOV		TOTAL	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total Observations	5056	100.0	5152	100.0	5152	100.0	5096	100.0	20456	100.0
Visibility Less Than 3 Miles	713	14.1	638	12.4	239	4.6	502	9.9	2092	10.2
Visibility Less Than 7 Miles	1253	24.8	1524	29.6	992	19.3	1264	24.8	5033	24.6
Smoke and/or Haze*	732	14.5	1109	21.5	725	14.1	830	16.3	3396	16.6
Dust*	0	0.0	6	0.0	0	0.0	0	0.0	6	0.03

*With visibility less than 7 miles.

Source: National Climatic Center (15)

of the time on an annual basis, with all of the occurrences during the spring (IAH 1970-1976) (12). All of these visibility and visibility related observations described above provide only a rough estimate of the actual visibilities, because visibilities in the Houston area frequently vary significantly with direction. Any such directional variations are qualitatively averaged for each individual observation, thereby introducing a significant error source.

Neutral stability conditions, as determined by the Pasquill-Turner classification scheme (17), occur more frequently than stable or unstable conditions (see Table 3-8). Stable conditions are the next most frequent condition, while unstable conditions are the least frequent atmospheric condition, year-round (1959-1968). Inversions (increasing temperature with height) within 500 feet above the ground are most frequent in fall and winter, for the hours of 6 am CST and 6 pm CST (see Table 3-9) (18).

Afternoon mixing heights are highest, on the average, during the summer and lowest during the winter, as might be expected because of changes in insolation. Conversely, afternoon transport winds are highest during the winter and lowest during the summer (see Table 3-9) (19). The mixing height is the height to which strong vertical mixing of the air takes place, while the transport wind is the average wind speed in the mixed layer. Ventilation, which is the product of mixing height multiplied by transport wind, is highest on the average in summer and fall, and lowest during the winter. Ventilation provides a measure of the ability of the atmosphere to disperse pollutants. High ventilation values, greater than about 6,000 meters squared per second, are generally considered to be associated with good dispersion conditions. Ventilation values of less than 4,000 meters squared per second, with transport wind speeds of four meters per second or less, are associated with air stagnation and poor dispersion conditions, while the 4,000 to 6,000 range may be considered marginally stagnant.

The number of air stagnation episodes for a five year period (1960-1964) are shown in Table 3-10 for various afternoon mixing heights and transport wind speeds. An exact determination of the number and duration of air stagnation episodes for that period is not possible because of a lack of upper air soundings for the Houston area. However, the data presented have been interpolated from tabulations for Lake Charles, Shreveport, and San Antonio (19). This interpolation provides an estimate of the occurrence of one air stagnation episode in the fall, with an afternoon mixing height of up to 1000 meters and a transport wind of four meters per second or less. Likewise, 12 episodes with an afternoon mixing height of up to 1500 meters and a transport wind of four meters per second or less are estimated. These 12 episodes covered an estimated total of 28 days. All of the episode totals presented above and in Table 3-10 are for five years. Also, only episodes lasting at least two days without significant precipitation have been included. The greatest number of episode days is estimated to have occurred during the fall for the two most stagnant cases described above.

TABLE 3-8. PERCENT FREQUENCY OF OCCURRENCE OF THE PASQUILL STABILITY CATEGORIES AT THE HOBBY AIRPORT 1959-1968

Stability	Pasquill Category	Season (%) DJF	MAM	JJA	SON	Annual (%)
Very Unstable	A	0.03	0.38	1.43	0.50	0.57
Unstable	B	1.63	3.13	8.03	4.99	4.38
Slightly Unstable	C	6.03	7.08	13.45	9.99	9.05
Near Neutral	D(day)	67.97	65.17	32.42	42.21	52.49
Near Neutral	D(night)	11.98	11.47	15.46	16.36	13.73
Stable	E and F	12.36	12.77	29.20	25.96	19.78

Sources: National Climatic Center (16)
National Climatic Center (17)

TABLE 3-9. LOW LEVEL INVERSION FREQUENCIES AND AFTERNOON MIXING HEIGHTS, TRANSPORT WINDS, AND VENTILATION FOR THE HOUSTON AREA

	Winter	Spring	Summer	Fall	Annual
Low Level Inversion Frequency (Percent of Total 6AM and 6PM CST Observations)	32	20	20	35	26
Afternoon Mixing Height (Meters)	900	1100	1500	1400	1200
Afternoon Transport Wind (Meters/Second)	7.5	7.0	5.5	6.0	6.5
Afternoon Ventilation (Meters Squared/Second)	6750	7700	8250	8400	7800

Period of Record: 1960-1964, except Inversion Frequency June 1955-May 1957

Sources: Hosler (18)
Holzworth (19)

TABLE 3-10. APPROXIMATE NUMBER OF EPISODES AND EPISODE DAYS FOR THE HOUSTON AREA IN 5 YEARS (1960-1964) FOR EPISODES LASTING AT LEAST 2 DAYS WITH NO SIGNIFICANT PRECIPITATION. (Number of Episodes/Number of Episode Days/Season*)

Afternoon Transport Wind (Meters/Second)	Peak Afternoon Mixing Height (Meters)			
	≤500	≤1000	≤1500	≤2000
≤2.0	0/0	0/0	0/0	0/0
≤4.0	0/0	1/2/F	12/28/F	20/47/SU
≤6.0	2/4/F	13/31/W	66/174/F	77/256/SU

* Season with greatest number of episode days, W-Winter, SP-Spring, SU-Summer, F-Fall

SOURCE: Holzworth, 1972.

COMPARISON OF THE AIR POLLUTION SITUATION IN HOUSTON WITH OTHER REGIONS

The combination of air pollutant emissions and meteorology in the Houston area create a unique air pollution situation for such a large city. Most other large cities in the United States are located in cooler, drier climates, with significantly lower percentages of contribution to total emissions from petrochemical industrial sources. The only large cities with similar meteorological environments are cities located along the Gulf coast and the south Atlantic coast, including New Orleans, Tampa-St. Petersburg, and Miami. Of these cities, New Orleans has the most similar environment to the Houston area because of its climate and petrochemical industries. However, even the New Orleans environment has significant differences from the Houston environment, mainly because of a higher air stagnation potential at New Orleans with a less pronounced land-breeze and sea-breeze influence on wind direction.

As a result of varying emissions and climates, air pollution composition and levels differ significantly between regions and even between some cities in the same region. Only a few cities have reported ozone levels near or greater than those reported in the Houston area. During the period 1974-1976, the Los Angeles, Fresno, San Jose, and Oakland areas in California, as well as Denver, Chicago, eastern Pennsylvania, and southwestern Connecticut reported ozone levels comparable to or higher than the Houston area (20). Data from 1974 (21) suggests that most cities the size of Houston, or larger, are reporting total hydrocarbon and nitrogen dioxide levels near or greater than in the Houston area, including New York City, Washington, St. Louis, Los Angeles, and San Francisco. Sulfur dioxide levels are generally higher in cities in the Northeast and the Great Lakes area than over the rest of the nation, including the Houston area (20). Also, total suspended particulate levels have generally been higher in urban areas of the north-central and northeastern U.S., as well as in the western U.S., than in the Houston area (20)- most notably in Pittsburg, Cleveland, Detroit, Chicago, St. Louis, Denver, and Los Angeles. These comparisons are only intended to provide a rough comparison of Houston with other large cities in the U.S. Clearly, a more detailed comparison of the air pollution situations in the Houston area with other regions is warranted on the basis that such comparisons should help in analyzing and solving the air pollution problems in all of these regions.

SECTION 4

ISSUES AND HYPOTHESES TO BE INVESTIGATED

The goals of the research addressed in this report are: (1) to improve understanding of the short- and long-term effects of air pollution on public health and welfare in the Texas Gulf Coast Area (TGCA) and, (2) to improve understanding of the character, impact, origin, transport, transformation and fate of air contaminants in the TGCA so that cost effective air pollution control strategies can be developed.

To effectively design an air pollution research program with limited funding it is necessary to focus all resources on the acquisition of information which will be most useful in providing a better understanding of the factors which affect air pollution levels and their impact. The approach used here is to first identify the principal issues (questions to which conflicting answers have been given) associated with air pollution in the TGCA. These issues then lead to hypotheses (unproven statements) to be investigated which in turn lead to experiments to be performed. These experiments generate data which require analyses. These analyses provide results which contribute to the resolution the issues. Figure 4-1 is a schematic of this process.

This section contains the principal issues and the hypotheses developed from these issues. Section 5 suggests experiments which will effectively test these hypotheses. A comprehensive research program is described in Section 6. Hypotheses regarding the public health effects of air pollutants in the TGCA are given in more detail in Volume II Plan for Health Effects Studies.

PRINCIPAL ISSUES AND HYPOTHESES

Table 4-1 contains the principal issues associated with the air pollution questions in the TGCA. Except for Issue No. 1 which concerns the uniqueness of the TGCA, and to a limited extent Issue No. 9 which concerns the impact of increased coal utilization, these issues are a statement of the general air pollution issues for the entire United States at this time. The issues have evolved during the past several years from studies of the air pollution problem and from attempts to implement the Clean Air Act and other legislation. In the research developed here these issues will be examined within the context of the TGCA.

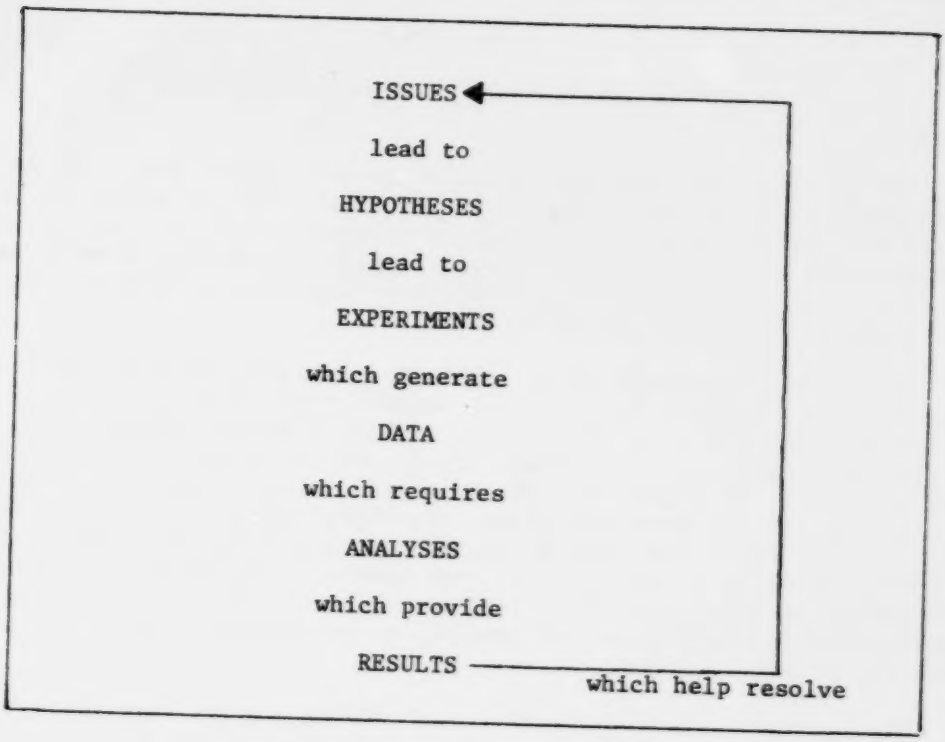

Figure 4-1. Components of research plan development.

TABLE 4-1. PRINCIPAL AIR POLLUTION ISSUES IN THE TEXAS GULF COAST AREA

1. UNIQUENESS OF THE TEXAS GULF COAST AREA
   - Are there unique pollutants or factors (meteorology, etc.) which exist in the TGCA and should be considered when setting air quality standards and/or designing emission control strategies?

2. CHARACTER AND EXTENT OF AIR POLLUTION LEVELS AND EMISSIONS IN THE TEXAS GULF COAST AREA
   - Have all of the important atmospheric pollutants in the TGCA been identified and/or characterized?

3. PUBLIC EXPOSURE VS POTENTIAL HEALTH HAZARD
   - What is the relationship between the measured ambient pollutant concentrations and the potential health hazard to the public?

4. SAMPLING AND ANALYTICAL METHODOLOGY VALIDITY
   - Are we accurately measuring pollutant levels?

5. PRIMARY VS SECONDARY POLLUTANTS
   - What is the relationship between source emissions and observed pollutants at an ambient receptor site?

6. LONG RANGE TRANSPORT OF POLLUTANTS
   - Is TGCA air quality significantly affected by long range transport of pollutants from other areas?

7. NATURAL VS ANTHROPOGENIC POLLUTANTS
   - To what extent do natural pollutants contribute to primary and/or secondary pollutant levels?

8. AIR QUALITY MODEL UTILITY
   - Can current air quality models accurately predict pollutant levels in the TGCA?

9. IMPACT OF INCREASED COAL UTILIZATION
   - How will increased coal utilization affect pollutant levels?

10. MOST COST-EFFECTIVE POLLUTANT CONTROL STRATEGIES
    - Can we directly or indirectly control the pollutants of concern in an economic and effective manner

The hypotheses presented in Tables 4-2 through 4-4 refine these issues to a set of specific unproven statements or questions relevant to air pollution in the TGCA. The specifity of the hypotheses permits experiments to be designed to amplify or resolve them.

Priorities are assigned to each hypothesis based on its estimated probable contribution to a better understanding of air pollution in the TGCA. Within each priority class, hypotheses are not ranked, only labeled numerically for reference. The issue or issues associated with each hypothesis are indicated.

TABLE 4-2. HIGH PRIORITY HYPOTHESES

1.1	Volatile organics to NO_x ratios are generally much larger in the TGCA than in other major urban areas. (1, 2, 5, 10)
1.2	Ground-level concentrations of O_3, NO_x, large-sized particles and SO_2 are sometimes significantly different from concentrations aloft. (2, 5, 6, 8)
1.3	Known or suspected carcinogenic or mutagenic compounds are present in significant quantities in airborne particulate matter in the TGCA. (1, 2, 3)
1.4	Organic aerosols in TGCA air are not hygroscopic. (2, 5)
1.5	A large percentage of the organic content of TGCA aerosol samples is polymeric. (2)
1.6	Airborne particulate samples from the TGCA have a significantly higher percentage of organic compounds than samples from other major urban areas. (1, 2)
1.7	Smaller aerosol particles (less than 3 μm) have a significantly higher percentage of organic compounds than larger particles in the TGCA. (2, 3, 5)
1.8	Elemental carbon (e.g., soot) is not a major constituent of TGCA airborne particulates. (2, 5, 7)
1.0	TGCA particulate samples are lower in sulfate and nitrate content than samples from other major urban areas. (1, 2, 5)
1.10	The percentage of sulfates and nitrates in smaller aerosol particles (less than 3 μm) is significantly greater than in large particles. (2, 5)
1.11	The metallic content of large airborne particles is significantly different from small particles. (2, 3, 5)
1.11a	The existing pollution monitoring network is insufficient for a determination of three-dimensional pollution levels in the TGCA (2, 4, 8, 9, 10)

Issues related to each hypothesis are in parentheses

(continued)

TABLE 4-2. (continued)

1.12 Some constituents of TGCA aerosols are highly volatile and/or unstable. (2, 4, 5)

1.13 Air pollutant concentrations actually experienced by most TGCA residents during their normal daily activities are significantly different from measured, outdoor ambient concentrations. (2, 3, 10)

1.14 Changes in atmospheric visibility in the TGCA is primarily due to changes in ambient relative humidity. (2, 3, 10)

1.15 Unidentified or unrecognized air pollutants significantly contribute to adverse public health effects in the TGCA. (2, 3, 10)

1.16 Only mobile sources directly emit significant quantities of volatile aldehydes into the TGCA atmosphere. (2, 3, 5, 6, 7)

1.17 The chemical composition of fugitive gaseous organic emissions from a stationary source is very similar to the point source emissions at the same source. (2, 5, 10)

1.18 Fugitive gaseous organic emissions from stationary sources comprise a large fraction of the total organic emissions from these sources. (2, 5, 10)

1.19 Each organic emission source category in the TGCA (stationary, mobile, and vegetative) emits unique organic compounds. (2, 5, 6, 7, 10)

1.20 Natural gaseous organic emissions comprise a significant fraction of the total organic emissions in the TGCA. (2, 5, 6, 7, 10)

1.21 The mixture of volatile organic compounds detected in ambient air is significantly different than the sum of all the volatile organic emissions. (2, 5, 6, 7, 10)

1.22 Trees in the TGCA emit significant quantities of organic vapors which easily form small particles (especially, condensation nuclei). (2, 5, 6, 7, 10)

(continued)

TABLE 4-2. (continued)

1.23 The emission rates of most stationary sources are highly constant with time (hourly, daily, seasonally and yearly). (2,5, 10)

1.24 Few stationary sources in the TGCA directly emit organic particles, (2, 5, 10)

1.25 High ^{7}Be and ^{32}P concentrations occur at ground level only when transport of air from the stratosphere has occured. (2, 10)

1.26 Mobile or stationary sources in the TGCA do not emit significant quantities of elemental carbon (e.g., soot). (2, 5)

1.27 Few emission sources in the TGCA directly emit small-sized (less than 3 μm) sulfate and nitrate particles. (2, 5, 6, 7)

1.28 Controlled stationary source emissions are primarily small-sized particles (less than 3 μm). (2, 5, 6, 7, 10)

1.29 Large quantities of small and/or large particles are emitted to the atmosphere in the TGCA due to ocean spray. (2, 5, 10)

1.30 Transport of ozone and haze from the central and southeastern U.S. may significantly influence air pollution levels in the TGCA. (1, 5, 6, 10)

1.31 O_3 transported from the stratosphere produces ground-level chemical reaction initiators which may cause high ground-level O_3 concentrations. (5, 7, 10)

1.32 O_3 transported from the stratosphere is a significant direct source of ground-level O_3 concentrations. (5, 7, 10)

1.33 Air transported into the Houston area which has not been influenced by stratospheric air frequently contains relatively high concentrations of O_3 and organic gases. (5, 6, 7, 10)

1.34 O_3 trapped aloft at night is frequently transported to ground-level by daytime mixing. (5, 10)

(continued)

TABLE 4-2. (continued)

1.35 O_3 trapped in layers aloft is relatively stable, especially during the night time hours. (2, 6, 7)

1.36 Ambient O_3 concentrations tend to be higher downwind of Houston. (2, 5, 6, 10)

1.37 Reduction in ambient organic concentrations alone will not result in significant reductions in ambient ozone or aerosol levels. (5, 6, 7, 10)

1.38 Stratospheric air is frequently transported to ground-level near synoptic frontal zones. (7, 10)

1.39 Release of waste heat in the downtown and ship channel areas of Houston significantly affects mesoscale air flow in the area. (10)

1.40 Aerosol levels are highly correlated with atmospheric ventilation, but ozone levels are not. (2, 5, 6, 7, 10)

1.41 Existing air dispersion models, reactive and non-reactive, are not useful for relating air quality to emission in the TGCA (1, 2, 5, 6, 8, 9, 10)

1.42 Photochemical reactions found to be important in oxidant formation in other regions of the country are not important in the TGCA. (1, 5, 6, 7, 8, 10)

TABLE 4-3. INTERMEDIATE PRIORITY HYPOTHESES

2.1	The ratio of total nonmethane organic vapors to total ambient oxides of nitrogen is highly variable in time and space in the TGCA. (2, 5, 10)
2.2	Ambient levels of ozone are not highly variable spatially in the TGCA except during stagnant weather conditions, (2, 5, 6, 7, 10)
2.3	Existing analytical methods for gaseous organics do not reliably identify organic compounds present in ambient air. (2, 4, 6, 7)
2.4	Existing aerosol, aeroallergen and organic vapor sampling techniques do not provide reproducible, representative ambient air samples suitable for chemical and/or physical analyses. (2, 4, 6, 7)
2.5	Under field operating conditions, existing methods for sampling ambient aerosols by size poorly discriminate particle size. (2, 4, 6, 7)
2.6	Aerosol particles in the TGCA have a higher relative water content than aerosols in other major urban areas. (1, 2, 6, 7)
2.7	Most airborne particles in the TGCA are coated with an outer liquid layer. (2)
2.8	Very small particles (condensation nuclei) are present in TGCA's atmosphere in lower concentrations than in other major urban areas. (1, 2, 5)
2.9	Most airborne particles from the TGCA do not absorb significant quantities of visible light, but do absorb considerable ambient thermal (IR) radiation. (2)
2.10	A few metallic elements (less than 10) occur in every total suspended particulate sample. (2)
2.11	Ambient concentrations of CO and SO_2 are generally low and spatially uniform in the TGCA except near specific emissions source areas. (2, 6, 7, 9, 10)

(continued)

TABLE 4-3. (continued)

2.12 Few sulfides as gases are present in the TGCA's atmosphere except in very localized source areas. (2, 5)

2.13 Carbonates and sulfides are not significant constituents of aerosol samples obtained in the TGCA. (2, 5)

2.14 Most metals are present in TGCA aerosol samples as oxides, not sulfates or nitrates. (2, 5)

2.15 Airborne asbestos levels do not significantly exceed rural background levels except in very localized areas. (2, 10)

2.16 Radioactivity of TGCA aerosol samples is low compared to local geologic background levels. (2)

2.17 Airborne pollen levels in the TGCA vary significantly with the seasons. (2)

2.18 Airborne molds, spores and bacteria are significantly higher in the TGCA than in other major urban areas. (1, 2)

2.19 Airborne particles in direct sunlight have a higher temperature than the air around them. (2)

2.20 Haze levels are generally higher in the downtown and ship channel areas of Houston, (2, 5, 10)

2.21 Total solar radiation and solar ultraviolet radiation differs significantly in intensity during hazy conditions below the lowest inversion layer. (2)

2.22 Economically significant vegetative classes are not affected by air pollution in the TGCA. (10)

2.23 Some air pollutants (e.g., CO, NO_x and organics) are present in higher concentrations indoors at work and home than in outdoor ambient air. (2, 3, 10)

2.24 Indoor concentrations of O_3 are significantly less than outdoor ambient concentrations. (2, 3, 10)

(continued)

TABLE 4-3. (continued)

2.25 Visibility has significantly deteriorated in the TGCA in recent years. (2)

2.26 Organic emissions from petroleum related stationary sources are primarily alkanes. (2)

2.27 Large amounts of gaseous ammonia are emitted by man-made and natural sources in the TGCA. (2, 5, 10)

2.28 Large-sized (greater than 3 μm) tire fragments only occur in aerosol samples near major traffic areas. (2, 7, 10)

2.29 Some stationary sources emit a unique "spectrum" of trace metals. (2, 6, 7, 10)

2.30 Some stationary source emissions are unique in the TGCA in one or more trace elment. (2, 6, 7, 10)

2.31 High ozone levels from stratospheric intrusion of air into the troposphere may persist in temperature inversion layers for long term periods of days or weeks. (7)

2.32 High ozone of stratospheric origin trapped in elevated temperature inversion layers may reach low enough elevations to become mixed to the surface by thermal or mechanical mixing near the ground, or by downrushing air associated with thunderstorms. (7)

2.33 Air pollution orginating from continental areas may sometimes cross the Gulf of Mexico before reaching the TGCA. (7)

2.34 Low visibility usually occurs with persistent northeasterly winds. (2)

2.35 Aerosols generated by ocean spray are often transported in significant quantities into the Houston area. (1, 5, 6, 7, 10)

2.36 The concentration of small-sized aerosols is not highly correlated with high ozone levels in the TGCA. (2, 5, 6, 7, 10)

2.37 Only small-sized (<3 μm) particulate emissions are tranported significant distances from their original emission source. (5, 6, 10)

(continued)

TABLE 4-3. (continued)

2.38 Some aerosol particles act as catalysts for the conversion of gaseous pollutants to solids or liquids. (5, 7, 10)

2.39 As airborne particles are transported through the TGCA, the particles increase in size by adding materials which are different for different source areas. (5, 6, 7)

2.40 Ambient O_3 is primarily removed by reaction with other airborne species (gases and aerosols). (5)

2.41 Hygroscopic gases and particles are removed from the TGCA atmosphere primarily by rainfall wash-out. (6)

2.42 Significant amounts of ambient nitrogen oxides are removed by conversion to nitric acid (10)

2.43 Ambient SO_2 is primarily removed by conversion to sulfates in the TGCA. (5, 9, 10)

2.44 Air pollution is not significantly affecting acidity of rain in the TGCA. (9, 10)

TABLE 4-4. LOW PRIORITY HYPOTHESES

3.1 Brown haze that occurs in the TGCA is primarily due to absorption of light by ambient levels of NO_2. (2)

3.2 Visibility in the Houston area is significantly lower than visibility in nearby rural areas. (2)

3.3 All of Houston is occasionally affected by objectionable airborne odors. (2)

3.4 Air pollution in the TGCA does not significantly affect the corrosion of exposed materials or buildings. (2, 10)

3.5 Absorption of light by airborne particles plays little part in reduction of visibility or discoloration of the TGCA's atmosphere. (2)

3.6 The composition of gaseous organic emissions from stationary sources differs significantly from mobile source emissions, (2, 5, 6, 7, 10)

3.7 Mobile or stationary sources in the TGCA do not emit significant quantities of carbonate particulates. (2, 5)

3.8 Total nonmethane volatile organic emissions are much larger in the TGCA than other major urban areas. (1, 2, 6, 7, 10)

3.9 SO_2 emissions in Houston are relatively small compared to other major urban areas. (1, 2, 9, 10)

3.10 Stable isotope ratios of sulfur, nitrogen and carbon containing emissions are significantly different for different emission sources in the TGCA (especially, anthropogenic versus natural). (2, 5, 6, 7)

3.11 The existing meteorological monitoring network is insufficient for a determination of mesoscale, three-dimensional air flow (up to 5000 ft.) in the TGCA. (8, 9, 10)

(continued)

TABLE 4-4. (continued)

3.12 Fugitive emissions are not transported as far as stack emissions of the same pollutant. (5, 6, 10)

3.13 A land-sea breeze regime occasionally recirculates air in the TGCA for several days. (1, 5, 6)

3.14 Mesoscale air flow is often affected by a land-sea breeze originating from the Gulf of Mexico. (1, 6)

3.15 High ambient temperatures in TGCA significantly affect atmospheric reactions. (1, 5, 7, 10)

3.16 Hygroscopic particulate emissions quickly become larger particles in the TGCA. (5, 7, 10)

3.17 The dominant psuedo-removal mechanism for airborne pollutants is many-fold dilution with clean air by normal atmospheric ventilation processes. (10)

3.18 Removal of pollutants by vegetation is insignificant in the TGCA. (10)

3.19 Ambient O_3 is not significantly removed by rainfall wash-out. (2)

3.20 Small-sized (less than 3 μm) aerosols are removed from the TGCA atmosphere primarily by settling as larger particles. (5, 10)

SECTION 5

PROJECT OPTIONS

Because of the interrelated nature of the suggested project options, the most efficient approach for conducting these projects would be to have one centralized program. The program approach would allow specific data collection for each individual project while providing common support services. Proper program management would reduce redundant tasks and allow each project to benefit from the others. A centralized data bank with common formatting would insure maximum utilization of data during this program and any follow-on analyses of the collected data.

Program tasks can be discussed in common terms for all of the involved projects including:

- review of existing relevant data,
- methods evaluation,
- collection of data,
- data processing and archiving,
- quality assurance, and
- data analysis including statistical analysis, gross correlations, case studies and modeling.

Through a centralized program, the individual efforts from each of the following projects described below can be brought together as meaningful parts of the whole problem.

The issues described in Section 4 can be investigated by collecting appropriate data and then interpreting the data with respect to selected hypotheses. The collection of data may involve field sampling and monitoring, or just the archiving and interpretation of existing data. The data analysis can be accomplished by statistical analysis, gross correlation analysis, case studies, and mechanistic modeling.

The projects outlined here are meant to serve as primary topics of investigation. The discussions should serve as a basis for developing a detailed scope of work. More detailed experimental plans for individual hypotheses will be required before execution of the project. Scheduling of some projects will in certain cases rely upon completion of a previously

conducted project. Others may be conducted simultaneously during a combined effort, or run parallel over similar or overlapping time frames.

ESTABLISH AND MAINTAIN A DATA BASE FOR THE TGCA

Initial efforts should be directed towards establishing a data base for the TGCA. This data base would provide all previously collected data pertaining to:

- TGCA air quality,
- TGCA emission sources, and
- relevant meteorological data.

Additionally, during the course of conducting all other projects, this data base must be maintained through continuous updating.

A consistent format for storing the data will need to be adopted, and consistent units should also be chosen. The SAROAD (Storage and Retrieval of Aerometric Data) format for monitoring data and the EIS (Emissions Inventory Subsystem) format for emissions data are examples of formats that could be used. The final format will need to be flexible enough to allow spaces for all of the parameters to be measured or inventoried, including detailed HC and detailed particulate data. A consistent set of units should be used for the entire data base to allow easy comparison of the data. This established format will serve as a guide to all study participants for furnishing results of specific projects and/or tasks.

The data base should be archived on both computer disc files and tape files. The disc files will provide easy access to the data. Tape files would serve as a back-up archive to help insure that no data is lost.

An emissions inventory is currently being conducted (during 1978) by the Texas Air Control Board. This inventory should be available during 1979 and will likely be expanded to give more detailed emissions data for hydrocarbons. The 1975 TACB Emissions Inventory is presently being re-evaluated to provide both point and area source data for NO_2, NO, SO_2, SO_4, nonreactive HC, olefins, parrafins, aromatics, and aldehydes in computerized form, in addition to the NO_x, THC, CO, SO_x, and PA data which is already available. A similar expansion for particulates may be needed to support possible modeling efforts. The most important particulate parameters for such an expansion would be particle size range and composition. All of the emissions data will also need to be archived on computer discs and tapes for easy access and back-up capability.

Additional processing of data will be needed for the generation of data summaries. These summaries will need to be arranged in a format that can be used for data analysis. Both tables and plots can be computer-generated to aid analysis. Also, summaries of data will be needed to show diurnal, monthly (or seasonal), and annual trends for both analysis and reporting purposes.

EVALUATE AND ANALYZE PRIOR TGCA STUDY RESULTS

Many hours of long-term ambient monitoring data and short-term research data are available for evaluation. After this information has been compiled, (data base) data can be evaluated for accuracy and completeness, and additional analyses may be conducted where warranted. This effort would serve to more completely define the key hypotheses requiring investigation in order to resolve various issues.

Three types of data analysis techniques are presented in Table 5-1. Statistical analysis and gross correlation analysis should be employed for studying large sets of data, and would be most appropriate for studying both old and new data sets. Case studies could be used to examine specific interesting episodes in much more detail than would be practical or possible for the long-term studies. Each of these types of analysis can be used to investigate:

- Upwind-downwind pollutant changes,
- Local pollutant transport,
- Long range pollutant or precursor transport,
- Weather conditions associated with high or low pollutant levels,
- Temperature or sunshine effects,
- Rainfall effects,
- Atmospheric ventilation effects, and
- Diurnal, seasonal, and annual trends of pollutant levels and interactions.

All of these analyses should help to reveal additional knowledge of the air pollution problems in the Houston area.

CONDUCT AN EXTENSIVE SOURCE CHARACTERIZATION STUDY

One of the prerequisites for understanding the contributions of various pollutant emissions to the observed air pollution burden is an accurate detailed characterization of air pollutant emissions in the TGCA. The relative contributions of industrial, transportation, natural, and distant emissions need to be determined as accurately as possible. Some of these emissions have a direct impact on observed ambient pollutant levels (primary pollutants), such as entrained dust and carbon monoxide. However, many emissions have an indirect effect (pollutant precursors), in that they influence the formation of pollutants such as oxidants and particulates. Both primary and precursor pollutant emissions need to be characterized.

Emissions of many important types of sources in the TGCA are poorly characterized. Detailed, quantitative measurements of selected sources are needed to better understand what airborne substances are being emitted into

TABLE 5-1. TYPES OF DATA ANALYSIS

1. Statistical Analysis - to include step-wise regression analysis, standard error analysis, correlation coefficients, partial correlations, and factor analysis of pollutant and meteorological parameters.

   Cost - $25,000 for one month of data, $5,000 extra for each additional month of data.

2. Gross Correlations - to include trend studies (annual, seasonal, and diurnal) and comparisons of pollutant and meteorological data (including air trajectories) from various locations and for various conditions covering the entire study period.

   Cost - $10,000 for one month of data, $3,000 extra for each additional month of data.

3. Case Studies - detailed investigation of specific episodes (particularly high ozone or high aerosol episodes - generally lasting 1 to 5 days) using trajectory analysis, and data comparisons.

   Cost - $6,000 for one case study, $3,000 for each additional case study.

the TGCA's air. Detailed hydrocarbon analysis and size-fractionated particulate sampling and chemical analysis is desirable (Table 5-2).

This information, when added to the previously established data base, will allow a more detailed pollutant balance to be constructed for the TGCA. In this manner the emitted pollutants can more completely be compared and/or contrasted to measured ambient pollutant levels.

CONDUCT AN EXTENSIVE AEROSOL CHARACTERIZATION STUDY

Based upon the analysis of past aerosol characterization results, it may be necessary to gather additional data. Two areas of study can be addressed to increase our knowledge of the nature of the TGCA aerosol:

- physical characterization and
- chemical composition.

Specific attention should be paid to the respirable aerosol fraction and characteristics related to decreased visibility. During such a study, additional measurements should be made to document meteorological conditions and levels of gas and/or vapor phase pollutants (Table 5-3).

Data analysis of the results of such a sampling effort should be directed toward answering specific hypotheses in an attempt to resolve such issues as:

- contribution of secondary aerosol vs. primary aerosol to the total suspended particulate level and the respirable particulate level and
- contribution of natural aerosol (sea salt, dust, etc.) vs. anthropogenic aerosol to the total suspended particulate level and the respirable particulate level.

Sample collection must be conducted in a way so that the aerosol composition is not affected. This requirement may involve extensive methods development and/or investigation in the areas of gain and/or loss of volatile components, gas-particle reactions and problems related to the high relative humidity in the TGCA.

PERFORM QUALITATIVE AND QUANTITATIVE ANALYSES OF AEROSOL SAMPLES

A complete knowledge of the chemical composition of the TGCA aerosol is needed to define the potential health hazard to the public-analysis should be performed to define levels of toxic metals such as arsenic and cadmium, as well as possible carcinogenic or mutenogenic agents such as polycyclic organic compounds. Close cooperation should be maintained with health effects studies to insure that analytical sensitivity and known exposure levels are compatable. The chemical composition of the aerosol will provide additonal information in the form of specific source contributions.

TABLE 5-2. SOURCE SAMPLING

Source Sampling - portable set of instruments to measure detailed HC, SO_2, SO_3, H_2SO_4, NO_x, NO, CO, and particle size distribution and chemical composition of various air pollution sources.
Cost - $50,000 per week, hired service.

TABLE 5-3. EXAMPLE POLLUTANT MONITORING PLATFORMS

1. **Baseline** - continuous monitoring of SO_2 and fuel combustion related radioactive isotopes, with rainfall acidity monitoring, TSP and possible monitoring of a few specific hydrocarbons or oxidants (which may be affected by control strategies).

   Cost - $15,000 per site initial costs (hired service for one month), $6,000 per month operating costs for one site, $4,000 per month operating costs for each additional site.

2. **Standard** - trailer configuration for continuous monitoring of O_3, NO_x, NO, THC, CH_4, CO, SO_2, WD, WS, TEM, (with NO_2 derived from NO_x-NO, and NMHC from THC - CH_4) and non-continuous monitoring of TSP.

   Cost - $40,000 per site initial costs (hired service for one month), $5,000 per month operating costs for one site, $2,000 per month operating costs for each additional site.

3. **Detailed** - site with O_3, NMHC, NO_x, NO, WS, WD, TEM, on a continuous basis, with detailed hydrocarbons, oxidants, and aerosols (with size fractionation and composition) preferably on a continuous basis.

   Cost - $40,000 per site initial costs, $20,000 per month operating costs for each site (hired service for one month)

   Note: Existing sites can be expanded to these capabilities.

4. **Mobile Ground** - truck or van instrumented to measure O_3, NMHC, NO_x, NO, aerosols, CO, TEM.

   Cost - $50,000 for one mobile station for one month hired service.

5. **Aircraft** - airplane or jet instrumented for O_3, ^{7}Be, NMHC, NO_x, aerosols and TEM, preferably capable of flying up to tropopause (30,000 to 40,000 feet).

   Cost - $75,000 per month (leased aircraft).

6. **Tall Building** - tall building (at least 500 feet) to be instrumented on roof to measure O_3, NMHC, NO_x, particulate (Hi-Vol), WS, WD, TEM preferably on a continuous basis.

   Cost - $30,000 for one site initial costs (hired service), $2,000 per month for one site operating costs (to be operated in conjunction with other ground stations).

7. **Ozonesonde** - O_3 monitor for vertical profile (twice daily) by balloon also to measure TEM and to be tracked by theodolite to provide WD, WS.

   Cost - $15,000 initial costs for one site, $6,000 per month operating costs for one site.

CONDUCT AN EXTENSIVE OXIDANT/HYDROCARBON STUDY

Much ozone/hydrocarbon data are currently available for the TGCA. If hypotheses concerning the nature of these pollutants and their relationship during periods of high concentration can not be answered during initial data analysis, additional studies may be warranted. If a study is conducted, meteorological data should be gathered to support the pollutant data.

Ozone data can be obtained from the regional monitoring network. Detailed hydrocarbon analysis, because of the nature of the analytical equipment required would be conducted on a short term basis. Attention should be given to sampling techniques [and samples should be analyzed in the field] to insure the integrity of the analytical results.

CHARACTERIZE NATURAL POLLUTANT EMISSIONS

The nature and magitude of natural pollutant emissions should be included in a complete emissions inventory for the TGCA. Identification of specific compounds and their respective emission rates from such natural area sources as green belts, coastal zones and agricultural plots are suggested.

Data should be collected during both night and daylight hours and related to relevant meteorological parameters (wind speed, incident radiation, etc.).

CONDUCT A PERSONAL MONITORING STUDY OF SELECTED POLLUTANTS.

Currently, ambient levels of pollutants are the only data available from which to draw conclusions concerning public exposure to harmful pollutants. A group of subjects could be chosen which would provide exposure information as a function of geographical location, outdoor activities, work place, etc. The pollutant levels associated with personal exposure can then be correlated to ambient levels. This information will be useful in assessing if ambient pollutant levels reflect public exposure.

Several methods could be employed to investigate these microscale pollutant variations, such as personal monitors, portable monitors, or multiple extended air intæk ducts from one centralized monitor (Table 5-4). Comparisons of pollutant levels inside various closed buildings with simultaneous pollutant levels in the open air outside would be useful. Also, variations of pollutant levels across street canyons, at building tops, within vegetated areas, and along major highways could be investigated. Finally, pollutant levels should be monitored within various rooms, offices, houses, or buildings where the general public typically can be exposed to air pollution accumulations. Enclosures with cooking, heating, air conditioning, or cigarette emission accumulations should be considered. Measurement methods that are compatible with outside ambient air monitoring should be used as much as possible for microscale monitoring.

TABLE 5-4. TYPES OF MICROSCALE MONITORING*

1. Personal - to be worn or carried by one person. Preferably, to be kept with one person continuously through the study period, and to provide average concentration of a given pollutant (O_x, PA, CO) for the entire study period. Recommend method evaluation prior to use.

2. Portable - set of instruments capable of measuring selected pollutants, preferably O_x, CO, NO_2, which can be easily moved by one or two people within most buildings.

   Cost - $3,000 per instrument initial costs (purchase), $2,000 per month operating costs.

3. Centralized Microscale - standard array of pollutant instruments for continuous monitoring, but with added capability to take samples from several nearby locations (preferably about 4 locations within about 100 feet) with hourly averages for each location created by alternating sample intake about every 5 minutes (with 4 locations this would give 4 five-minute averages per hour for each location).

*Abbreviations are listed at the beginning of the report.

CONDUCT AN AIRBORNE PROFILE OF POLLUTANT FLUX INTO AND OUT OF THE TGCA

An important issue in the TGCA air pollution problem is the contribution of pollutant sources outside the area to the total pollutant burden. Vertical profiling of pollutants at select perimeter locations can help resolve this issue. An airborne sampling platform would be required (Table 5-3) with extensive supplemental meteorological monitoring support (Table 5-5).

Additional support of such a study could come in the form of synoptic scale monitoring.

The deployment of monitors on a synoptic scale would probably be impractical for the TGCA. However, local, state, and federal monitors already are being operated in most states, and data from such monitors which may be helpful in synoptic scale studies should be obtained. Ozone, NMHC, NO_x, particulate, and meteorological data from the midwestern and southeastern states would be most useful.

CONDUCT A PLUME TRACKING STUDY

As a result of a source characterization study and ground level pollutant monitoring, specific sources can be chosen for a plume tracking study. Such a study would concentrate on answering hypotheses directed towards pollutant transformations and source - receptor relationships. This study would include a variety of sampling platforms (Table 5-3). Meteorological support would again play a key role in the successful completion of the study.

Pollutants to be measured should be selected as the result of postulated hypotheses concerning the identified pollutants emitted at the source and their role in pollutant transformation during transport. The information gained can support and/or suggest situations for study in chamber or captive air studies.

CONDUCT CHAMBER AND/OR CAPTIVE AIR STUDIES

To help establish various emission contributions, a better understanding of the mechanisms which lead to secondary pollutant formation is necessary.

Studies of chemical reactions, as well as gas-particle and particle-particle interactions in a Houston-related environment are needed. Chamber studies and captive air experiments, could be most useful (Table 5-6). However, care must be taken to insure that the air being studied is truely representative of the Houston environment. For chamber studies, ultra violet radiation, temperature, and humidity should reflect the variations present for Houston. For captive air studies, experiments with the sampled air should be conducted immediately after capture to reduce the possibility of significant chemical interactions occurring before tests are made. Detailed pollutant

TABLE 5-5. EXAMPLE METEOROLOGICAL MONITORING PLATFORMS

1. Meteorological Tower - preferably an existing tall tower (at least 500 feet, with an elevator) to be instrumented for continuous measurement of WD, WS, TEM, DP (or RH) at three levels (preferably top, middle, and bottom) with TEM at two additional intermediate levels.

   Cost - $25,000 for one site, initial costs, $1,500 per month operating costs for one site.
   Note: Various pollutant monitors may be added.

2. Radiosonde - balloon with transmitter to provide vertical profiles of WD, WS, TEM, DP (or RH), and pressure up to 10,000 feet, to be tracked by theodolite (twice daily).

   Cost - $10,000 initial costs for one site, $3,000 per month operating costs for one site, $1,000 per month extra for one additonal release per day.
   Note: National Weather Service releases could be expanded, $200 per run.

3. Tethered Balloon - balloon tethered to ground by cable, to reach variable heights up to about 2,000 feet, with instruments for O_3, WD, WS, TEM, DP, and pressure.

   Cost - $15,000 initial cost for one site, $6,000 per month operating cost.
   Note: Ozone measurement could be included.

4. Instrumented Tetroon - super pressure balloon designed to remain at constant pressure level in the atmosphere, to be instrumented to measure O_3, TEM, and pressure (one release per day).

   Cost - $30,000 per month (with leased automatic tracking equipment).

5. Tri-Axis Acoustic Sounder - a vertical acoustic sounder accompanied by two additional transmitters grouped to provide vertical profiles of all three wind direction components (u, v, w) and temperature structure to at least 300 meters.

   Cost - $35,000 per site initial costs (purchase) with $2,500 per month operating costs for one site and $2,000 per month extra for each additional site, $5,000 initial costs (lease) with $5,000 per month per site.

(continued)

TABLE 5-5. (continued)

6. FM/CW Radar - frequency modulation/continuous wave radar capable of measuring vertical profiles of WD, WS up to at least 10,000 feet and to show layers of refractive index changes (associated with temperature inversions).

   Cost - $30,000 for one month, $45,000 for two month Houston study by NOAA Wave Propagation Lab personnel.

7. Dual Doppler Radar - doppler radar to measure three-dimensional WD, WS fields using chaff dropped from aircraft.

   Cost - $75,000 for one month Houston study by NOAA Wave Propagation Lab personnel.

8. Laser - laser with receiver to measure backscatter (would prefer additional capability to have laser beam reflected and received to measure pollutant absorptions) to provide mixing height, turbulence, and temperature verticle profiles.

   Cost - $60,000 for one month trial run (one site, hired service).

TABLE 5-6. TYPES OF RESEARCH

1. Chamber studies - closed chamber studies of chemical reactions and physical interactions which cause secondary pollutant formation, in air simulating the Houston environment (especially emissions, temperature, and humidity variations), with emphasis on photochemical reactions and secondary particulate formation.

   Cost - $40,000 per month for one chamber (20 tests for one month).

2. Captive Air Experiments - closed chamber studies using captured ambient air mixed with known quantities of reactive gases, preferably with immediate mixing of test gas and ambient sample to avoid changes within the ambient sample before the test gas is introduced.

   Cost - $175,000 for one month field study, $50,000 for each additional month.

monitoring, especially for hydrocarbons and aerosols (including continuous monitoring of size fraction and composition) are needed for these studies. Results from these studies should also benefit the quality of air pollution models.

VALIDATION AND/OR DEVELOPMENT OF AIR POLLUTANT MODELS

If a thorough and complete understanding of the air pollution problem in the TGCA can be realized, a predictive model can be developed (Table 5-7). Both development and validation of such a model can only be realized if the data of interest is available in a concise, usable data base. Current air quality models should first be evaluated using the collected source inventory and ground level pollutant levels. If unique meteorological conditions or pollutant transformations are identified and their effects substantiated, models will have to be developed to describe them.

CONDUCT LONG TERM MONITORING

Following the completion of an intensive study period, such as described by the above projects, consideration should be given to monitoring of select pollutants on a long term basis. Such a project could be at the same level of effort as current regional monitoring networks, with inclusion of any other paramters (meteorological) required (Table 5-3 and 5-5).

METEOROLOGICAL SUPPORT TASKS

Meteorological support throughout the projects described above is essential. In addition, a specific meteorological project(s) may be warranted, including some of the monitoring platforms described in Table 5-5. Meteorological conditions affect chemical reactions and interactions as well as pollutant concentration and distribution. To assess these effects, a better knowledge of atmospheric conditions in the Houston area is needed. Pollutant concentration, stability, wind, and humidity below 10,000 feet (or about 3,000 meters) are the most important parameters to be measured. Present monitors do not adequately provide vertical profiles of these parameters on even a daily basis. Vertical profiles of pollutant concentration, stability, wind, and humidity should ideally be obtained 3 or 4 times daily, and preferably at two or more sites located along a line perpendicular to the coast, to obtain adequate information.

Surface monitors at present provide an adequate network for most meteorological paramters (except for solar radiation). However, to assist in upwind-downwind studies and to characterize ambient rural pollutant concentrations, 2 or 3 upwind monitoring sites are needed to cover the most predominant wind directions. Present monitoring sites may be adequate for downwind analysis, though an additional 1 or 2 monitors at distances substantially further downwind than present locations would be helpful. Also, several pyranometers and/or ultra violet radiometers are needed on a more permanent basis at several locations.

TABLE 5-7. VALIDATION AND/OR DEVELOPMENT OF AN AIR POLLUTION MODEL

Modeling -	to include development and testing of photochemical oxidant and aerosol models and the use of these models to make predictions of future air pollution levels, with development of one single model to describe both oxidants and aerosols to be considered.
	Cost - $200,000 per model.

Several types of meteorological studies can be employed. Theoretical air parcel trajectories, both forward and backward in time, can be used to evaluate short-range and long-range pollutant transport. Statistical analysis, gross correlations, and dispersion modeling (for a coastal environment) can be used to study relations of meteorological parameters to pollutant concentrations. Mesoscale models of air flow in the TGCA should be evaluated.

QUALITY ASSURANCE DURING DATA COLLECTION

Throughout any project arrangements for quality assurance checks of the collected data must be made. Guidelines for quality assurance need to be established to insure that the final data base will contain only good quality data. Siting of instruments, calibration procedures, and data validation procedures will all affect the data quality. Guidelines for siting and calibration that should be adopted for the TGCS have been published by the EPA. These include the "Ambient Monitoring Guidelines for Prevention of Significant Deterioration" (EPA-450/2-78-019, May 1978) and the "Quality Assurance Handbook for Air Polution Measurement Systems, Volume I, Principles" (EPA-600/9-76-005, March 1976).

The PSD monitoroing guidelines are applicable for continuous monitoring of O_3, NO_2, CO, SO_2, and meteorological data, as well as non-continuous TSP monitoring. In general, the instruments are required to be sited at locations that are not significantly obstructed from air flow or unduly influenced by nearby pollutant sources. Continuous analyzers are required to use EPA-designated Reference or Equivalent Methods, with calibrations performed during installation, and recalibration whenever:

- The control limit is exceeded for the span check,
- repairs are made, or
- major components are replaced.

Single-point span checks are required at least once per week for continuous pollutant monitors, with periodic independent multi-point audits.

The Quality Assurance Handbook provides a more comprehensive view of quality assurance than the Ambient Monitoring Guidelines for PSD, including siting, calibration, and validation. Some of the guidelines from both reports are irrelevant to the TGCS, but both contain many guidelines that could serve well for the TGCS.

An independent audit program will be needed to assure that monitoring conducted for specific projects will meet standard guidelines.

SECTION 6

RESEARCH PROGRAMS

Previous sections have discussed principal air pollution issues and experiments to address those issues. The limited financial resources available to study these problems will not permit all issues to be resolved. Six options have therefore been developed which emphasize different aspects of the overall pollution problem.

In each case a total budget of three million dollars is assumed, with a program duration of thirty-six months or less. This budget includes health effects studies, the details of which are addressed in a separate volume of this report.

The various program options are based on the premise that the studies will be conducted in the Houston area. The large amount of data from previous studies plus the current existence of nine continuous monitoring stations provide an overall cost effectiveness not matched by other Gulf Coast locations. (Seven stations are operated by the City of Houston and two by the Texas Air Control Board. Numerous industrial monitors also exist.)

For each of the six program options, certain combinations of studies of the type discussed in Section 5 are proposed. These individual studies are summarized in Table 6-1. Estimated cost and duration is provided for each type of study. Finally, how each program option addresses the key issues described in Section 4 (Table 4-1) is discussed.

TABLE 6-1. POSSIBLE PROJECTS

A	Establish and Maintain a Data Base
B	Analysis of Prior TGCA Study Results
C	Characterization of Existing Sources
D	Aerosol Characterization Study
E	Detailed Analysis of Aerosol Samples
F	Detailed Oxidant/Hydrocarbon Study
G	Characterization of Natural Emissions
H	Personal Monitors
I	Pollutant Flux Into and Out of the TGCA
J	Plume Tracking Study
K	Chamber or Captive Air Studies
L	Development/Validation of Models
M	Long Term Monitoring
N	Meteorological Studies
O	Quality Assurance

PROGRAM PLAN I - SUPPORT FOR HEALTH EFFECTS STUDIES

This program focuses on the collection of data to support health effects studies in the Houston area. The studies should be designed to make maximum use of the data from the existing monitoring stations. Additional data will be provided by the program described below.

Study Type	Funding	Time/Duration (beginning - ending months)
A - Establish and Maintain a Data Base	$50,000.	0 - 4
B - Analysis of Prior TGCA Study Results	$100,000.	3 - 12
C - Characterization of Existing Sources	$250,000.	12 - 14
D - Aerosol Characterization Study	$300,000.	12 - 24
E - Detailed Analysis of Aerosol Samples	$300,000.	12 - 24
F - Detailed Oxidant/ Hydrocarbon Study	$200,000.	12 - 24
H - Personal Monitors	$200,000.	12 - 24
O - Quality Assurance	$100,000.	0 - 24

Total Cost - $1,500,000.

Half of the money will be used for the health effects studies. Since this support program is providing input data, the analysis and reporting will be part of the health effects portion. One year has been reserved for this program.

In project F above, the bulk of the money is intended to be used in expanding the instrumentation at the existing monitoring stations. The source characterization in project C is to examine a cross-section of industries for potentially hazardous emissions. Projects A and B will be oriented toward health effects - related parameters and studies.

The issue which will be primarily addressed in this program plan include (see Table 4-1):

- Public Exposure vs. Potential Health Hazard (Issue 3)

Issues which will be partially addressed include:

- Character and Extent of Air Pollution Levels and Emissions in the Texas Gulf Coast Area (2) and

- Uniqueness of the Texas Gulf Coast Area (1).

PROGRAM PLAN II - INTENSIVE SAMPLING PROGRAM COMBINED WITH MODEL DEVELOPMENT/ VALIDATION

In this program the focus is on intensive data collection projects to support the development of model(s) for the Houston air pollution problem. Health effects studies are included, but at a decreased level of emphasis.

Specific projects include:

Study Type	Funding	Time/Duration (beginning - ending months)
A - Establish and Maintain a Data Base	$75,000.	0 - 4
B - Analysis of Prior TGCA Study Results	$200,000.	3 - 12
C - Characterization of Existing Sources	$300,000.	12 - 14
D - Aerosol Characterization Study	$250,000.	12 - 14
E - Detailed Analysis of Aerosol Samples	$200,000.	12 - 14
F - Detailed Oxidant/ Hydrocarbon Study	$200,000.	12 - 14
G - Characterization of Natural Emissions	$50,000.	12 - 14
I - Pollutant Flux Into and Out of the TGCA	$150,000.	12 - 14
J - Plume Tracking Study	$150,000.	12 - 14
K - Chamber or Captive Air Study	$250,000.	14 - 18
L - Development/Validation of Models	$400,000.	12 - 24
N - Meteorological Studies	$200,000.	12 - 14
O - Quality Assurance	$100,000.	0 - 24
Total Cost - $2,525,000.		

This program leaves slightly less than a half million dollars for health effects studies. Analysis and reporting costs are included in project L, model development and validation. Costs for study design are included in project B.

Issues addressed directly by this program plan include:

- Primary vs. Secondary Pollutants (5),
- Long Range Transport of Pollutants (6), and
- Air Quality Model Utility (8),

Issues addressed partially by this program plan include:

- Uniqueness of the Texas Gulf Coast Area (1),
- Character and Extent of Air Pollution Levels and Emissions in the Texas Gulf Coast Area (2),
- Public Exposure vs. Potential Health Hazard (3),
- Natural vs. Anthropogenic Pollutants (7),
- Impact of Increased Coal Utilization (9), and
- Most Cost-Effective Pollutant Control Strategies (10).

PROGRAM PLAN III - DETAILED STUDY OF THE OCCURRENCE AND DISTRIBUTION OF HAZARDOUS POLLUTANTS

This study focuses on the identification of potentially hazardous substances in Houston's atmosphere, and on their sources and distribution. Maximum use will be made of existing stations, with significant expansion of their capabilities.

Specific projects include:

Study Type	Funding	Time/Duration (beginning - ending months)
A - Establish and Maintain a Data Base	$75,000.	0 - 4
B - Analysis of Prior TGCA Study Results	$250,000.	4 - 12
C - Characterization of Existing Sources	$350,000.	12 - 14
D - Aerosol Characterization Study	$300,000.	12 - 24
E - Detailed Analysis of Aerosol Samples	$500,000.	12 - 24
F - Detailed Oxidant/ Hydrocarbon Study	$500,000.	12 - 24
G - Characterization of Natural Emissions	$50,000.	12 - 24

H - Personal Monitors	$150,000.	12 - 24
O - Quality Assurance	$100,000.	0 - 36
Data Analysis and Reporting	$100,000.	24 - 36
	Total Cost - $2,375,000.	

Chemical analysis costs for detailed analysis of trace organics, inorganics, and trace metals will consume a major part of projects C, E, F, G, and H. Relocateable stations will be used extensively in D and F. Personal samples (H) will be used to characterize human exposure to potentially hazardous species.

Some $625,000. will be available for health effects studies. These studies should begin after data are available on the occurrence and distribution of hazardous species.

Issues addressed directly by this program plan include:

- Character and Extent of Air Pollution Levels and Emissions in the Texas Gulf Coast Area (2) and
- Public Exposure vs. Potential Health Hazard (3).

Issues addressed partially:

- Uniqueness of the Texas Gulf Coast Area (1) and
- Natural vs. Anthropogenic Pollutants (7).

PROGRAM PLAN IV - DETAILED AEROSOL STUDY

This program plan focuses on a detailed characterization of aerosols and their sources. Hydrocarbons and oxidants are studied only as they pertain to aerosols. Existing monitoring stations will be expanded to support intermittent sampling and continuous physical characterization of aerosols. Existing meteorological stations will be used.

Specific projects include:

Study Type	Funding	Time/Duration (beginning - ending months)
A - Establish and Maintain a Data Base	$50,000.	0 - 4
B - Analysis of Prior TGCA Study Results	$150,000.	3 - 12
C - Characterization of Existing Sources	$325,000.	12 - 15
D - Aerosol Characterization Study	$500,000.	12 - 18

E - Detailed Analysis of Aerosol Samples	$500,000.	12 - 18
F - Detailed Oxidant/ Hydrocarbon Study	$200,000.	12 - 18
G - Characterization of Natural Emissions	$100,000.	12 - 18
I - Pollutant Flux Into and Out of the TCCA	$150,000.	12 - 18
J - Plume Tracking Study	$75,000.	12 - 18
O - Quality Assurance	$100,000.	0 - 18
Analysis and Reporting	$100,000.	18 - 30

Total Cost - $2,250,000.

Project D will include a detailed assessment of visibility in Houston's atmosphere, and its relationship to various types of aerosols. Program definition is included in project B.

Some $750,000. will be devoted to health effects studies, which should be oriented toward aerosol - related effects for maximum program effectiveness. These should be conducted during the last year of the study.

Issues addressed directly by this program plan include:

- Character and Extend of Air Pollution Levels and Emissions in the Texas Gulf Coast Area (2),
- Primary vs. Secondary Pollutants (5), and
- Natural vs. Anthropogenic Pollutants (7).

Issues addressed partially by this plan include:

- Uniqueness of the Texas Gulf Coast Area (1),
- Public Exposure vs. Potential Health Hazard (3),
- Sampling and Analytical Methodology Validity (4),
- Long Range Transport of Pollutants (6), and
- Most Cost-Effective Pollutant Control Strategies (10).

PROGRAM PLAN V - DETAILED OXIDANT/HYDROCARBON STUDY

This program plan focuses on the oxidant/hydrocarbon problem. Aerosol sampling will be confined to that necessary to support the oxidant/hydrocarbon study. Existing monitoring stations will be expanded to support detailed hydrocarbon and oxidant analysis. These will be supplemented with relocateable monitoring stations.

Specific projects include:

Study Type	Funding	Time/Duration (beginning - ending months)
A - Establish and Maintain a Data Base	$75,000.	0 - 4
B - Analysis of Prior TGCA Study Results	$200,000.	3 - 12
C - Characterization of Existing Sources	$250,000.	12 - 14
D - Aerosol Characterization Study	$100,000.	12 - 18
E - Detailed Analysis of Aerosol Samples	$100,000.	12 - 18
F - Detailed Oxidant/ Hydrocarbon Study	$500,000.	12 - 18
G - Characterization of Natural Emissions	$100,000.	12 - 18
I - Pollutant Flux Into and Out of the TGCA	$150,000.	12 - 18
J - Plume Tracking Study	$150,000.	12 - 18
K - Chamber or Captive Air Studies	$350,000.	18 - 24
N - Meteorological Studies	$200,000.	12 - 18
O - Quality Assurance	$125,000.	0 - 36
Analysis and Reporting	$125,000.	24 - 36
	Total Cost - $2,425,000.	

Program definition is included in project B. Project I, J, and N will be used to define transport into and out of the Houston area. $575,000. is available for health effects studies.

Issues addressed directly by this program plan include:

- Character and Extent of Air Pollution Levels and Emissions in the Texas Gulf Coast Area (2),
- Primary vs. Secondary Pollutants (5),
- Long Range Transport of Pollutants (6), and
- Natural vs. Anthropogenic Pollutants (7).

Issues addressed partially by this program include:

- Uniqueness of the Texas Gulf Coast Area (1),
- Public Exposure vs. Potential Health Hazard (3),
- Sampling and Analytical Methodology Validity (4), and
- Most Cost-Effective Pollutant Control Strategies (10).

PROGRAM PLAN VI - COMBINED AEROSOL-OXIDANT-HYDROCARBON STUDY

This program plan combines the objectives of the two previous program plans, but with less detailed work in each area. As before, instrumentation in existing stations will be supplemented extensively.

Specific projects include:

Study Type	Funding	Time/Duration (beginning - ending months)
A - Establish and Maintain a Data Base	$75,000.	0 - 4
B - Analysis of Prior TGCA Study Results	$200,000.	3 - 12
C - Characterization of Existing Sources	$250,000.	12 - 16
D - Aerosol Characterization Study	$350,000.	12 - 18
E - Detailed Analysis of Aerosol Samples	$350,000.	12 - 18
F - Detailed Oxidant/ Hydrocarbon Study	$350,000.	12 - 18
G - Characterization of Natural Emissions	$100,000.	12 - 18
I - Pollutant Flux Into and Out of the TGCA	$100,000.	12 - 18
J - Plume Tracking Study	$100,000.	12 - 18
N - Meteorological Studies	$150,000.	12 - 18
O - Quality Assurance	$150,000.	0 - 30
Analysis and Reporting	$200,000.	
Total Cost -	$2,375,000.	

Project B includes costs for program definition. Project N will support transport and characterization studies. $625,000. will remain for health effects studies.

Issues addressed directly by this program plan include:

- Character and Extent of Air Pollution Levels and Emissions in the Texas Gulf Coast Area (2),
- Primary vs. Secondary Pollutants (5),
- Long Range Transport of Pollutants (6), and
- Natural vs. Anthropogenic Pollutants (7).

Issues addressed partially by this program include:

- Uniqueness of the Texas Gulf Coast Area (1),
- Public Exposure vs. Potential Health Hazard (2),
- Sampling and Analytical Methodology Validity (4), and
- Most Cost-Effective Pollutant Control Strategies (10).

SECTION 7

AIR POLLUTION RESEARCH CAPABILITIES OF LOCAL PUBLIC AGENCIES

Several local and state public agencies have or currently are conducting research on the origin, transformation and fate of air contaminants in the Houston area. This section describes the resources that might be available through these agencies to assist in the execution of a comprehensive Texas Gulf Coast Research Plan.

Table 7-1 lists all the agencies surveyed in this study. Other public agencies which are capable of participating in an air pollution research study may have inadvertently been omitted from this survey. The resources identified below for each agency are based solely on verbal interviews. Additional resources may be available which were not discussed in the interviews. Specific resource availability for the Texas Gulf Coast study will depend on prior commitments and EPA needs.

GOVERNMENTAL AGENCIES

Four state and local governmental agencies that conduct air pollution monitoring and/or research were surveyed. Tables 7-2, 7-3 and 7-4 summarize the resources that might be available for participation in a Texas Gulf Coast research study. While the Texas Department of Highways and Public Transportation has air quality and meteorological monitoring instruments, their availability is limited due to statewide commitments.

UNIVERSITIES

Eight local universities were surveyed. Tables 7-5, 7-6, 7-7, 7-8, 7-9 and 7-10 summarize available resources of those universities surveyed. While two universities (Prairie View A&M University and Rice University) have environmental curricula, they do not presently have resources available to support an air pollution research study in the Houston area.

TABLE 7-1. PUBLIC AGENCIES SURVEYED

Agency	Contact
Government	
Texas Air Control Board	Steve Spaw, Austin
Texas Department of Highways and Public Transportation	Rod Moe, Austin
Harris County Air Pollution Control Department	Allison Pierce, Pasadena
City of Houston Health Department	Ken MacKenzie, Houston
Universities	
Baylor University	Dr. Merle Alexander, Waco
Prairie View A&M University	Dr. John Williams, Prairie View
Rice University	Dr. Bedient, Houston
St. Thomas University	Dr. Freeman, Houston
Texas A&M University	Dr. A. McFarland, College Station
University of Houston	Dr. Frank Worley, Houston
University of Texas at Austin	Dr. Hal Cooper, Austin
University of Texas at Houston	Dr. Gazelle, Houston

TABLE 7-2. RESOURCES OF THE TEXAS AIR CONTROL BOARD

Type of Research	Resources	Feasibility of Participation
Air Chemistry	1. Continuous monitoring for O_3, NO, NO_x, CO THC, CH_4, SO_2, TS, and b_{scat} (heated and unheated) at two sites in the Houston area.	a. Can voluntarily support research program in limited way with resources and manpower.
	2. Intermittent monitoring (every sixth day) for TSP, (>25 sites), RSP (6 sites), heavy metals (all sites), sulfates, nitrates and gases, ammonia, (total aldehydes, nitrogen dioxide, chlorine).	b. EPA grant possible.
	3. Special analytical capabilities include detailed organic analysis using temperature programmable gas chromatographs with FID, EC or mass spectrometer detectors, liquid and ion chromatographs, atomic absorption spectrometer and optical microscope.	c. Major long-term participation will require negotiation between agency and EPA.
Meteorology	4. Continuous monitoring of WS, WD, TEM, RH at two sites, and UV solar radiation (1 site).	

TABLE 7-3. RESOURCES OF HARRIS COUNTY

Type of Research	Resources	Feasibility of Participation
Air Chemistry	1. Special analytical capabilities include four gas chromatographs, (one with a mass spectrometer detector), (UV, IR fluorescence) and spectrometers, and a liquid chromatograph.	a. Limited b. EPA grant possible. c. Major long-term participation will require negotiation between agency and EPA.

TABLE 7-4. RESOURCES OF THE CITY OF HOUSTON HEALTH DEPARTMENT

Type of Research	Resources	Feasibility of Participation
Air Chemistry	1. Continuous monitoring for O_3 (6 sites), NO/NO_x, CO, THC/CH_4, TS/SO_2 in the Houston area.	a. Limited. b. EPA grant possible.
	2. Intermittent monitoring (every sixth day) for TSP, sulfates, Cu, Pb, Mn, Cr, Ni, NO_2, SO_2, aldehydes and ammonia at over 25 sites.	c. Major long-term participation will require negotiation between agency and EPA.
	3. Special monitoring of ragweed pollen at five sites every Fall.	
	4. Routine analysis of Pb in gasoline samples from service stations.	
	5. Special analytical capabilities include temperature programmable gas chromatograph with FID and EC detector.	
	6. Helicopter and boat for specialized sampling	
Meteorology	7. Some of air quality monitoring stations are equipped with 10 meter towers with WS, WD and TEM sensors	

TABLE 7-5. RESOURCES OF BAYLOR UNIVERSITY, INSTITUTE FOR ENVIRONMENTAL STUDIES

Resources	Feasibility of Participation
1. One twin-engine aircraft (Cessna 336A) equipped with sampling manifold, air quality monitors for O_3, NO_x, and SO_x, nephelometer, ambient temperature, and total solar radiation. Four wavelength photometer also available. Data from continuous instruments collected by automatic data logger and reduced by ground-based minicomputer.	a. Actively solicits grants for air pollution research including EPA funding. b. Available to participate in Texas Gulf Coast research program.
2. Ground-based standards laboratory for calibration of O_3, NO_x and SO_x instruments.	

TABLE 7-6. RESOURCES OF ST. THOMAS UNIVERSITY, INSTITUTE FOR STORM RESEARCH

Resources	Feasibility of Participation
1. Real-time weather data and forecasting for the Texas Gulf Coast and surrounding areas.	a. Actively solicits funding for air pollution research from EPA and others.
2. Meso and microscale models of air movements.	b. Available for support of Texas Gulf Coast research study.
3. Theoretical interpretation of local meteorological data.	

TABLE 7-7. RESOURCES OF TEXAS A&M UNIVERSITY

Resources	Feasibility of Participation
1. Development, testing and calibration of size-fractionating aerosol samplers. Chemical analysis of aerosol samples.	a. Solicit grants for air pollution research from EPA and others.
2. Detailed organic analysis of gaseous and aerosol samples.	b. Potentially available for Texas Gulf Coast study depending on timing and scope of work.
3. Estimation of suspended particulate matter emissions from agricultural processes.	
4. Modeling of emissions from mobile sources.	

TABLE 7-8. RESOURCES OF THE UNIVERSITY OF HOUSTON

Resources	Feasibility of Participation
1. Special analytical equipment available include four gas chromatographs (one with mass spectrometer detector, three with FID, EC and TC detectors), scanning electron microscope, auger x-ray, and casade aerosol samplers with hi-vols.	a. Actively solicits funding for air pollution research from EPA and others. b. Available for participation in Texas Gulf Coast research study.
2. Mathematical model development and testing for homo- and heterogeneous atmospheric reactions. IBM 360 and other computers available.	
3. Special experience in organic analysis of complex gaseous and aerosol mixtures using GC/MS.	

TABLE 7-9. RESOURCES OF THE UNIVERSITY OF TEXAS AT AUSTIN

Resources	Feasibility of Participation
1. Development, testing and calibration of aerosol sampling and monitoring devices. Participates in intensive aerosol field sampling programs.	a. Actively solicits funding for air pollution research from EPA and others.
2. Monitoring capabilities include O_3, SO_x, acid rainfall, organics using GC/FID, FPD and EC, mercury, atomic absorption spectrometry, and neutron activation analysis.	b. Available for participation in Texas Gulf Coast research study.
3. Dispersion modeling of air pollutants using CDC 6600 and other computing facilities.	

TABLE 7-10. RESOURCES OF THE UNIVERSITY OF TEXAS AT HOUSTON

Resources	Feasibility of Participation
1. Analytical instrumentation include a gas chromatograph with EC, FID and TC detectors, spectrophotometers (IR, UV, and visible), atomic absorption spectrometer, cascade impactors and low-energy X-ray spectrometer.	a. Potentially available for research-oriented projects.
2. Analysis and interpretation of air pollution research data.	

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